U.S. Bur. of Naval Personnel

AIRCRAFT STRUCTURAL MAINTENANCE

Prepared by

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PREFACE

This book is written for the purpose of presenting to the enlisted men of Naval Aviation the essential information on procedures used in the maintenance and repair of aircraft. This is one of a series of books designed to furnish them with the necessary information to perform their aviation duties.

The latest materials and processes used in aircraft maintenance and repair have been described from a utilitarian point of view, since the technical data in this volume is based largely upon Army, Navy, and Federal specifications. Unimportant details have been purposely omitted in the interest of brevity and readability, and consequently, this book is rather general in scope and should meet the needs of all Aviation Structural Mechanic ratings.

Beginning with a discussion of Aircraft Structural Elements, Basic Stresses, and the various properties of Aircraft Materials, this book continues with explanations of Blueprint Reading and Layout, the Uses of Aircraft Tools and Equipment, Fabrication Procedures, Aircraft Riveting, Fasteners, Structural Repairs, Repairs of Tanks and Tubing, and the Repair and Maintenance of Rubberized Equipment, Plastics, and Fabric Coverings. It concludes with a section on Metalite.

As one of the NAVY TRAINING COURSES, this book represents the joint endeavor of the Naval Air Technical Training Command and the Training Publications Section of the Bureau of Naval Personnel.

STUDY GUIDE

The table below indicates which chapters of this book apply to your rating. To use the table follow these rules:

1. Select the column which applies to your rating. If you are in the Regular Navy you will use the column headed AM; if you are in the Navel Reserve you will use the column headed by your particular emergency service rating, AMS or AMH.

2. Observe which chapters have been marked in your rating column with the number of the rate to which you are seeking advancement.

3. Study those particular chapters. They include information which will assist you in meeting the qualifications for your rating. To gain a well rounded view of the duties of the General Service Rating it is recommended that you read the other chapters of this book even though they do not pertain directly to your rating. Here is an example. If you are a member of the Naval Reserve studying for advancement to the rate of AMH3, you will select the column headed AMH. Follow this column down and you will observe that you must study chapters 1 through 8.

Chapter	AM	AMS	AMH
1	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
2	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
3	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
4	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
5	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
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7	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
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Aircraft Materials—NavPers 10330.
Aircraft Welding—NavPers 10322-A.
Aircraft Hydraulics—NavPers 10332-A.
Blueprint Reading—NavPers 10077.

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Information and Education officer.* A partial list of those courses applicable to your rate follows:

Number	*Title*
J200	*Aerodynamics.*
J204	*Airplane Maintenance I.*
J205	*Airplane Maintenance.*
J362	*Arc Welding.*
J363	*Gas Welding.*
EM912	*Blueprint Reading at Work.*
EM965	*Machine Tool Operation.*
EM970	*Mathematics for Technical and Vocational Schools.*
J277	*Sheet Metal Drafting.*

* Members of the United States Armed Forces Reserve components when on active duty are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more regardless of the time specified in the active duty orders.

AIRCRAFT STRUCTURAL MAINTENANCE

CHAPTER I

AIRCRAFT STRUCTURAL MAINTENANCE

UNITS OF AIRCRAFT STRUCTURE

The aircraft of today still retains many of the elements essential for controlled flight that were incorporated in the Wright brothers' first successful airplane. To visualize modern aircraft construction and repair, you must understand these basic structural and control features.

The basic structural and control components of a modern airplane are the FUSELAGE, ENGINE MOUNTS, WINGS, STABILIZING SURFACES, and CONTROL SURFACES.

FUSELAGE

The fuselage is the main structure or body of the airplane. It houses the crew and the cargo. To the fuselage are attached the wings, empennage, and often the landing gear of the craft.

WELDED STEEL TRUSS

Figure 1.—Truss-type fuselage.

Fuselages of the various types of airplane have much in common from the standpoint of outline and general design. They vary mainly in size and in arrangement of the different compartments. In single-engine aircraft, the power plant is mounted on the nose of the fuselage, but on multi-engine aircraft, nacelles are usually attached to the wings for this purpose. Detail design varies with the manufacturer, and the requirements of the service for which they are intended. Figure 1 illustrates the truss-type, or basic fuselage, which, although rapidly becoming obsolete, nevertheless illustrates the fundamental principles of the aircraft "bony structure." This type of fuselage is generally used on light airplanes which are fabric-covered.

Fuselages of most military airplanes are of all-metal construction, assembled in a modification of the MONOCOQUE DESIGN which relies largely on the strength of the skin or shell (covering) to carry the various loads. This design may be divided into three classes—monocoque, semimonocoque, and

reinforced shell. Different portions of the same fuselage may belong to any of these classes.

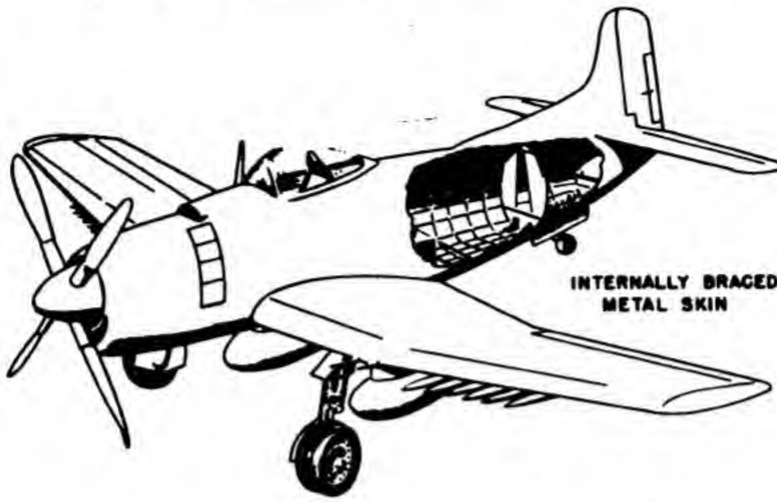

Figure 2.—Semimonocoque fuselage.

The monocoque has vertical rings, station webs, and bulkheads for reinforcement. The semimonocoque has its skin reinforced additionally by longitudinal members (stringers and longerons) but, like the monocoque, it has no diagonal web members. The reinforced shell, used mainly on larger ships, has the skin reinforced by a complete framework of structural members, the cross-sectional shape is derived from bulkheads, station webs and rings, and longitudinal contour is developed with longerons, formers, and stringers. Formers and stringers may be single pieces or built-up sections.

The skin, or covering, which is fastened to all these members, primarily carries the shear load, and with the longitudinal members, it carries the loads of tension and bending stresses. Station webs are built-up assemblies located at intervals to carry concentrated loads. You'll find station webs at points where fittings are used to attach external parts such as wings, landing gear, and engine mounts.

The metal in general use for fuselage construction is aluminum alloy. The two aluminum alloys which are most used are 17ST and 24ST. These metals are about one-fourth as heavy as steel and after being heat-treated approximately one-fourth as strong as mild steel. For surface covering,

aluminum alloys are made in sheets with a thin coating of pure aluminum. The coating protects the base metal from oxidation. In this form the metal is known by the trade names of ALCLAD and PURECLAD.

ENGINE MOUNTS

Engine mounts are used to attach the power plant to the aircraft. On most single-engine aircraft, they are mounted to the front end or nose of the fuselage. On the majority of multiengine planes, they are attached to or incorporated with the nacelle structure which is connected to the wing.

Engine mounts are designed to meet particular conditions of installation, such as the location and the method of attachment of the engine mount and the size, type, and characteristics of the engine it is intended to support. Although mounts vary widely in appearance and arrangement of members, the basic features of construction are similar. An engine mount is usually constructed as a single unit which may be detached quickly and easily from the remaining structure.

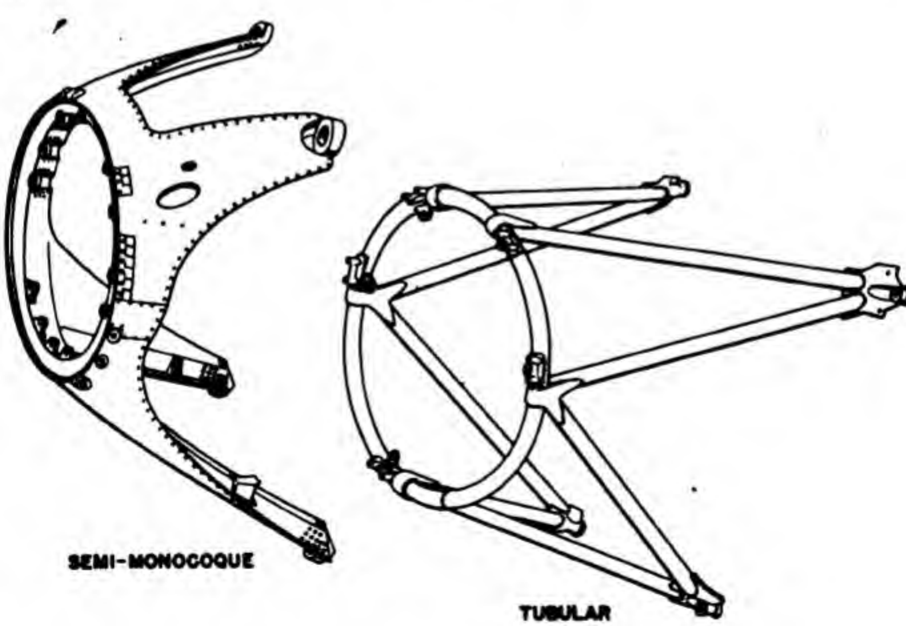

Figure 3.—Semimonocoque and tubular engine mounts.

A primary consideration in design of engine mounts is the necessity of making the engine and its equipment accessible for maintenance and inspection. A framework construction of welded chrome-molybdenum steel tubing is well adapted to this purpose and is used extensively, although engine mounts are also formed of corrosion-resistant steel. Forgings of chrome-nickel molybdenum steel are used for the more highly stressed fittings.

Although the exact location of the engine mount depends entirely on the design of the airplane, points of attachment of the mount are either at, or just forward of, a flame-tight, fireproof bulkhead. This bulkhead which separates the engine compartment from the rest of the structure is called the firewall.

WINGS

Aircraft wings are surfaces designed to furnish lift when the airplane moves rapidly through the air. The particular wing design for any given aircraft depends upon a number of factors such as the size, weight, and use of the aircraft; the desired landing speed; and the desired rate of climb. Frequently the larger compartments of the wings contain, or are themselves used as, tanks.

Variations in design and construction depend upon the manufacturer and upon specifications outlining assignment and performance requirements. Wing structures of most Navy planes are of all-metal construction and are usually of the cantilever design, that is, so constructed that no external bracing is required. With few exceptions they are all of the stressed-skin type, in which the skin is a part of the wing stresses.

A typical wing design involves two main spars with ribs and bulkheads placed at frequent intervals between the spars to space them and develop wing contour. Other types of wing design include the monospar and the multispar types. During flight, applied air loads which are imposed on a wing structure act primarily on the wing covering. From the

covering loads are transmitted to the ribs and from the ribs to the spars. The spars support all distributed loads as well as concentrated weights, such as fuselage and power plants.

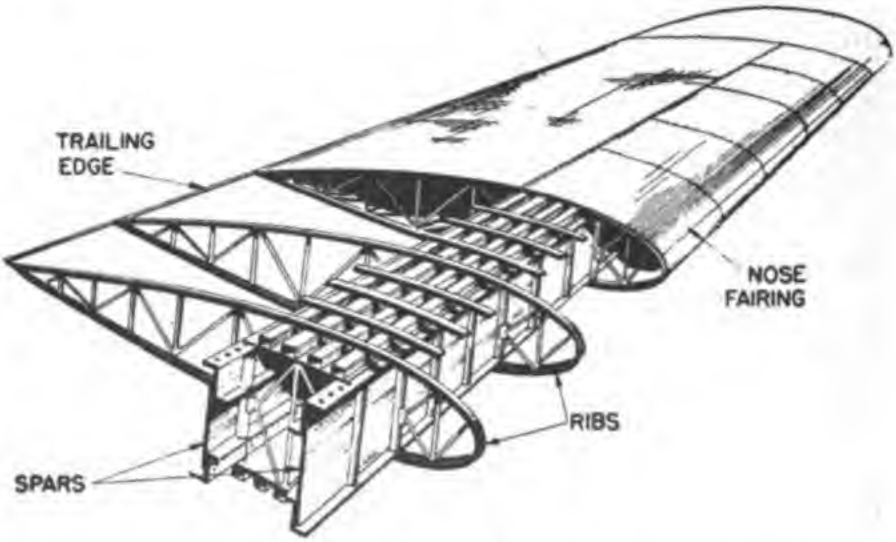

Figure 4.—A typical wing.

Corrugated sheet aluminum alloy is often used as a subcovering for wing structures. The smooth outer covering is usually attached with either flush-head or brazier-head rivets placed fairly close together, and the joints are carefully fitted so that the stresses on the wing coverings are evenly distributed.

As in the case of fuselages, the metal in general use for wing structures is of heat-treated aluminum alloy. Either ALCLAD or PURECLAD is used for the outer covering when corrosive-resistant properties are desired. Wings of some aircraft, particularly those used for training, are covered with fabric or plywood. Fabric covering is made taut and protected against deterioration by several coats of a cellulose-base material known as airplane dope.

STABILIZING SURFACES

Stabilizing units of an airplane consist of vertical and horizontal airfoils which are parts of the empennage, or tail

assembly. The vertical surface is generally called the fin, and the fixed horizontal surface is generally referred to as the stabilizer.

Figure 5.—Stabilizing surfaces.

Construction features of fixed tail surfaces are in many respects identical with those of wings. The fixed tail surfaces are usually of all-metal construction and of the cantilever type. They have two main members or spars and ribs to which the metal skin is attached. Fabric-covered structures may be braced against drag with internal tie rods. Fairings are used to round out the angles formed between the fixed tail surfaces and fuselage.

The fin maintains stability of the aircraft about its turning or vertical axis (directional stability). This unit also serves as the base or anchorage to which the rudder is attached.

The stabilizer provides stability of the aircraft about its lateral axis (longitudinal stability). The stabilizer is similar to the fin in internal construction and it also serves as a support for the elevators.

FLIGHT CONTROL SURFACES

Flight control surfaces are hinged or movable airfoils designed to change the attitude of the aircraft during flight. They consist of the main group, the auxiliary group, and landing flaps.

The MAIN GROUP is made up of ailerons, elevators, and rudders by which the aircraft is moved about its various axes.

The AUXILIARY GROUP is composed of trim tabs, balance tabs, and servo tabs used for reducing the force required to operate main control surfaces, or for trimming and balancing aircraft in flight.

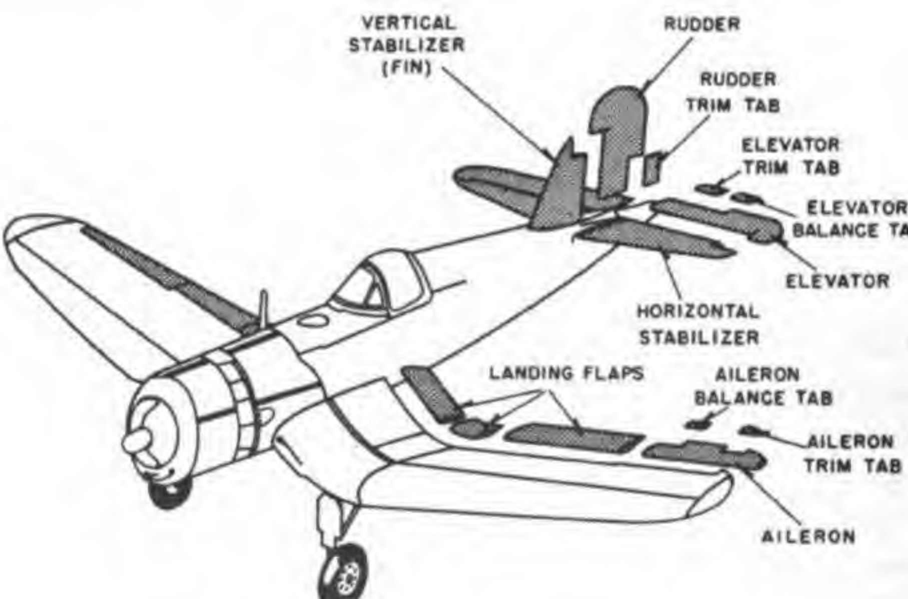

Figure 6.—Control surfaces.

LANDING FLAPS are intended to reduce landing speed of fast aircraft, shorten the length of the landing run, and facilitate landing in small or obstructed areas by permitting the gliding angle to be increased without appreciably increasing the gliding speed.

QUIZ

1. What are the basic structural and control components of an airplane?
2. What are the functions of station webbs?
3. What is a primary consideration in the design of engine mounts?
4. A wing design that requires no external bracing is known as what type of design?
5. What units comprise the main group of flight control surfaces?

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CHAPTER 2

BASIC STRESSES AND METAL PROPERTIES

AIRPLANE CONSTRUCTION

Before an Aviation Structural Mechanic can make repairs to aircraft structures, he must understand their various functions and the basic stresses involved. This is especially true if major repairs are required.

In designing an airplane every square inch of wing and fuselage, every rib, spar, and even each metal fitting must be considered in relation to the physical characteristics of the metal of which it is made. Every part of the craft must be planned to carry the load to be imposed upon it. This figuring of loads is called stress analysis. While planning the design is not a job for the mechanic, it is nevertheless, essential that he appreciate its importance. You'll find an understanding of design an invaluable aid to avoiding changes in the original design through repairs.

An understanding of the following terms is necessary in the study of materials and their use in aircraft construction.

TERMS RELATING TO PHYSICAL CHARACTERISTICS

In flight an airplane is buffeted about by the elements. The plane parts are, therefore, constantly subjected to such forces as tension, compression, shear, bending, and torsion. Usually a combination of these forces exist at any given time, but to understand the result of these collective forces, you must first consider the physical properties individually.

Every airplane is a compromise between two factors—weight and strength. Each pound of weight added to an airplane cuts down its flying efficiency. This relationship between the strength of a material and its weight per cubic inch expressed as a ratio is called the STRENGTH-WEIGHT RATIO. Since neither strength nor weight alone can be used as a basis for true comparison, the strength-weight ratio forms the basis for comparing the desirability of various metals for use in aircraft construction.

Fatigue failure occurs in materials which are subjected to frequent reversals of loading or repeatedly applied loads, if the fatigue limit is reached or exceeded. Repeated vibration or bending will ultimately cause a minute crack to occur at the weakest point of a material. As vibration or bending continues, the crack progresses until complete failure of the part results. This is known as fatigue failure and resistance to this condition is known as fatigue resistance.

Fatigue failures in aircraft parts may originate from a number of causes, dependent upon design or processing. Many instances of failure may be traced to nicks, scratches, corrosion, or other damage to the surface of metals. It is highly important that care be exercised to avoid tool marks or other damage to metals to prevent fatigue failures.

Torque is a twisting force such as would occur in a member fixed at one end and twisted at the other. The TORSIONAL STRENGTH of material is its resistance to torque.

Bending may be described as the deflection or curving of a member due to forces acting upon it. The BENDING STRENGTH of material is the resistance it offers to deflecting forces.

HARDNESS refers to the ability of a material to resist abrasion, penetration, indentation, or cutting action. The wearing qualities of a material are dependent upon its hardness. Hardness and strength are properties which are closely related. Parts such as bearings and stressed shafts must possess hardness to resist wear and strength to sustain loads.

BRITTLENESS is the property of a material which permits little bending or deformation without fracture. Brittleness and hardness are closely associated.

A metal which can be hammered, rolled, or pressed into various shapes without fracturing or other detrimental effects is said to be malleable. This condition is necessary in sheet metal which is worked into curved shapes such as cowling, fairing, and wing tips. MALLEABILITY and brittleness are opposite characteristics.

DUCTILITY is the property of a material which permits it to be permanently drawn, bent, or twisted into various shapes without fracture. Wire used in control cables and electrical conductors is drawn from ductile material. Ductility is similar to malleability.

ELASTICITY is that property which enables a material to return to its original shape when the force which causes the change of shape is removed. This property is especially desirable in springs.

A material which possesses toughness will resist tearing or shearing, and may be stretched or otherwise deformed without fracturing. TOUGHNESS is a desirable property in aircraft materials and is the opposite of brittleness.

HEAT CONDUCTIVITY is the property of a material which determines the rate of transfer of heat within the material. Metals vary in their ability to conduct heat. Aluminum alloy has a relatively high rate of heat conductivity and therefore is used in cylinder heads of air-cooled engines to dissipate the heat of combustion.

The TENSILE STRENGTH of a material is its resistance to a force which tends to pull it apart. Tensile strength is measured in pounds per square inch and is calculated by dividing the load (in pounds) required to pull the material apart by its cross-sectional area (in square inches).

The COMPRESSIVE STRENGTH of a material is its resistance to a crushing force. Compressive strength of a material is measured in pounds per square inch. Landing-gear shock absorbers are subjected to compressive forces.

The resistance offered by a material to a force tending to cause one layer of the material to slide over an adjacent layer is known as its SHEARING STRENGTH. Two riveted plates in tension subject the rivets to a shearing force. Usually the shearing strength of a material is either equal to or less than its tensile or compressive strength.

The hardening of metals by cold working or forming is termed WORK-HARDENING. Stainless steel is hardened by cold working and heat treating. Bending or hammering copper tubing produces undesirable work-hardening characteristics. Vibration also produces undesirable work-hardening effects. These effects may be removed by annealing to lessen the possibility of fracturing.

QUIZ

1. What is failure of a part because of repeated vibration or bending called?
2. What is a twisting force called?
3. What word describes a property of a material that cannot be bent or deformed without failure?
4. What property is possessed by a material that can be hammered, rolled, or pressed into various shapes without fracturing?
5. What units are used to express tensil strength?

CHAPTER 3

BLUEPRINT READING AND LAYOUT

The first time you look at a blueprint for a part or assembly you may say to yourself, "That sure doesn't look like anything that belongs on or in any airplane I ever saw." You will be right, too, since a blueprint is not a picture or ordinary line drawing of an object, but a way of showing its true size and shape by means of lines and symbols. After you learn to read blueprints the lines and symbols on the print will give you a true picture of the part, along with the other information you must have to duplicate it. In your job of maintaining and repairing aircraft, blueprints are as much a part of your tools as hammer and snaps. All your skill as a craftsman with hand and power tools won't mean much if you can't read blueprints.

WHAT IS A BLUEPRINT?

You will hear the terms blueprint, drawing, and print used interchangeably. For all practical purposes, they all

mean the same thing, that is, a reproduction of a mechanical drawing. The word blueprint comes from the method of reproducing mechanical drawings which has been in use in most industries for a number of years. To make a blueprint, the draftsman makes a pencil drawing, the drawing is placed over a chemically treated white paper called blueprint paper, and exposed to strong light in the blueprint machine.

The lines on the original drawing keep the light off the blueprint paper. Where the light strikes the blueprint paper it turns gray. When the blueprint paper is removed from the blueprint machine, and rinsed in water, the portion exposed to light turns blue, and the lines protected from light by the lines on the original drawing remain white. The result is a blueprint with the mechanical drawing shown in white against a blue background.

There are other similar methods of reproducing mechanical drawings that employ different papers and developing processes. Depending upon the paper and developers used, there are Ozalids, which may be maroon, black, purple, or blue against a white background; and Van Dykes, which may have white lines against a dark brown background. The word print now has a wider meaning than the original term and refers to any reproduction of a mechanical drawing whether the blue color is present or not.

NOW LET'S BEGIN TO READ A PRINT

Get an aircraft print, any print will do, and open it out on the table where you are studying. Before you start to puzzle out the lines and symbols on the print proper, look for the title block. It will usually be in the lower right-hand corner although you may find it elsewhere. Without even looking at the drawing you can get a lot of information from this title block. Here you will find the name of the part, unit, or assembly. Drawing titles are given in telephone directory style—identification first, description second. For example, flange—carburetor air intake—is simply the carburetor air intake flange. In other words, the noun is given first, and then the descriptive phrase. The location of the part may

be included in the drawing title. Thus you may read: elevator and tab assembly—left (showing that the part belongs on the left side). The size of the drawing is not always the same size as the object, so you will have a space in the title block labeled Scale. In this block you will find the number of inches on the part represented by parts of inches on the print. Thus, you may have one half inch equals one inch, which would mean that the drawing was one half the size of the actual part. When you see the word "Full" in the scale block, you will know that the dimensions of the print are the same as the dimensions of the part or assembly.

Each part of an airplane has a part number. The part number and the blueprint number may be the same, but if they are not, the part number is shown somewhere in the title block.

Each blueprint, whether it is a detailed unit, subassembly, or final assembly, has a number. You won't have any trouble locating this number because it will be the largest and most conspicuous number on the blueprint.

RIGHT-HAND AND LEFT-HAND PARTS

Many aircraft parts on the left-hand side of an aircraft are exactly like the corresponding parts of the right-hand side except that they are mirror images of each other and not two identical parts. A left-hand part does not necessarily go on the left-hand side of an airplane. For example an assembly in the right-hand wing may contain both right hand and left-hand parts.

Usually where only a drawing of a left-hand part is made, the right-hand part is given the same number with a ONE added. For example, the title block might read: "6163492 LH shown; 6163492–1 Right-hand opposite." All aircraft companies do not follow this policy in numbering right- and left-hand parts. Some companies use odd numbers for left-hand parts and even numbers for right-hand parts while some companies do the opposite. Still others assign numbers with no regard to whether they are odd or even. You must learn the practice of the manufacturer of the airplane on which you are working and follow that.

In general, the dash numbers system is used when detailed parts of an assembly are dimensioned on their assembly. One aircraft manufacturer places each of the dash numbers in a circle close to the part it identifies, followed by the name (noun only), with an arrow running from the circle to the border of the part. An encircled dash number must not appear in more than one place on a drawing. On large drawings dash numbers are located by zone numbers in the material block.

The basic number is usually the left-hand part, and dash 1 (– 1) is used only to indicate the right-hand part as explained in the paragraph on right- and left-hand parts.

ZONE NUMBERS

You know how the mail delivery in large cities is speeded by including a zone number in the address. This zone number serves to identify a section of the city. Large blueprints are also divided into zones so that when you are reading the blueprint you can find what you are looking for. The first 10.40 inches from the right border is zone 1. From this point to a point 5 inches beyond the title block is zone 2. Eleven-inch zone spacing is continued to the left-hand vertical border of the drawing. The last zone may be any width up to 11 inches and its zone number appears in the left-hand lower corner.

STATION NUMBERS

There are various numbering systems in use to help you find such things as wing frames, stabilizer frames, and fuselage frames. Most manufacturers use some system of station marking, for example, the nose of the airplane may be designated as the Zero Station and the other stations are located at measured distances in inches behind the Zero Station. Thus when a blueprint reads, "fuselage frame station 137," that means that the frame is 137 inches behind the nose. To locate structures to the right and left of the center line of

the plane, the center line may be taken as the Zero Station for objects on its right and left. With this system the wings and stabilizer frames can be located as being so many inches right or left of the airplane center line. On some drawings the fire wall is the Zero Station and on other drawings the leading edge of the wing may be used as Zero Station for certain purposes. Always locate the Zero Station before looking for other stations.

ASSEMBLY NUMBERS

When a part shown on a blueprint is to be part of an assembly, an assembly number is given to indicate the drawing number of another print which gives the information necessary for completing the assembly. The number of parts required such as one for the right hand and one for the left hand is also given and is listed under the "Per Ship Number Reqd."

MATERIAL

The title block will tell you what material to use for a particular part or assembly. This information is contained in the blocks headed "Material" and "Specification." The material column tells you the material that is to be used for constructing the parts. The specification block specifies exactly what kind of material, for example, the material block may state that 0.040 sheet aluminum is required for the part, and then specifies that it must be 24 S–T which is a hard aluminum alloy. On most of the prints you see the material specification will be coded. The finish or protective coating may also be indicated by code, or it may be written in clear language.

When heat treatment is required it should be specified in the title block although it is sometimes placed on the drawing itself.

DIMENSIONS, LIMITS, AND TOLERANCE

Some blueprints will show only detailed dimensions. By consulting the space labeled "size" on the title block, you can

get the over-all dimensions. Notice that three dimensions are given. Always read them in this order: Thickness, Width, and Length.

Limits are the extreme permissible dimensions of a part. You will find the limits in a block labeled "limits unless otherwise specified." The dimensions on the print represent the optimum size. For example, the basic dimension of the length of an object might be 6 inches with limits of plus or minus 0.005. From these limits you could tell that the part could be made 5.995 inches or 6.005 inches long and still fit.

In order that you will not confuse limits and tolerance, let's compare the two terms while limits are still fresh in your mind. Tolerance is the range of error between the limits that will be accepted or tolerated. In the above example of limits they were given as plus or minus 0.005. The plus limit is the dimension plus 0.005 and the minus limit is the dimension minus 0.005, and the tolerance is 0.010.

OTHER INFORMATION

There is other information in the title block, but you need not be too concerned with it. You will find the names of the draftsmen, checkers, and other personnel who produced the drawings; the actual and calculated weight of the part; the drawing area; and the name of the manufacturer is included in the title block.

HOW YOU LOOK AT IT

Now that you are familiar with the information that is given in the title block, you are ready to look at the drawing. Before the lines and symbols mean much to you, you will have to understand the principles involved in making a mechanical drawing.

A mechanical drawing is an orthographic projection. Other types of drawing are perspective, oblique, and isometric. These types of drawings present an over-all view of the object, but when you read a blueprint you want more than a view of the part. Also, each view must be presented

without distortion. An orthographic projection usually shows three views of an object. (See fig. 7.)

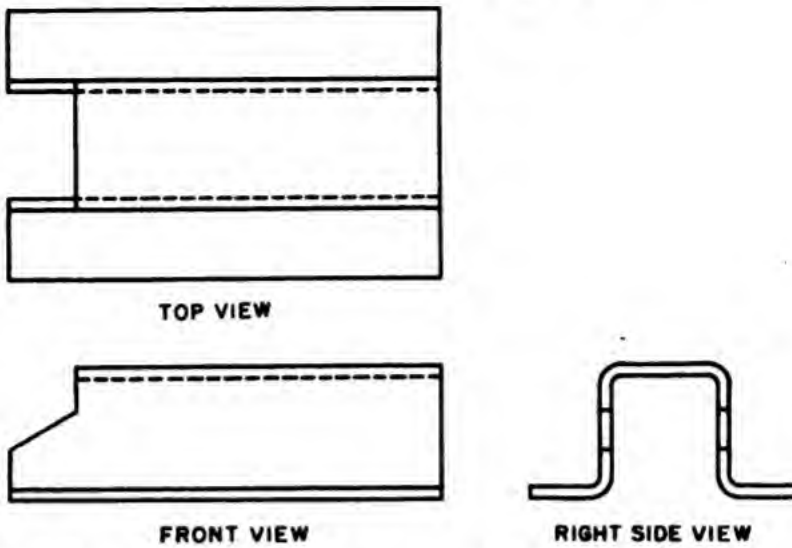


Figure 7.—Orthographic projection showing three views of a simple U bracket.

If you have the bracket shown in figure 7 and place it on a table in such a manner that you are looking directly down on it, you will see much the same thing as is shown in the top view of figure 7. Now if you lower your head until your line of sight is even with the top of the table, you will see the view that corresponds to the front view. Now turn the bracket 90° to the right and you will see the right side view as it appears in figure 7.

When a draftsman begins a drawing, he starts with the front view. The front view is the view that shows the most characteristic feature of the object. All other views are considered in relation to the front view. The projection to the right of the front view is the right-side view; the view above the front view is the top view; if the left view is shown, it will appear to the left of the front view; the bottom view will be below the front view.

LINES

Of course you know that what you learn about the shape of an object from a blueprint you get from the lines on the print. Figure 8 shows the lines you will ordinarily find on a print. Refer to this figure as you read the following:

BORDER LINES: (VERY HEAVY)
HEAVIEST LINE ON DRAWING.

OUTLINE OF PART: (HEAVY)
THE PART OUTLINE IS THE OUTSTANDING FEATURE OF THE DRAWING.

HIDDEN LINES: (HEAVY)
THIS LINE IS MADE UP OF SHORT DASHES AND INDICATES A LINE OR LINES HIDDEN FROM VIEW BY SOME PORTION OF THE PART.

CROSS SECTION LINES: (HEAVY)
THESE LINES SIGNIFY MATERIAL THAT HAS BEEN CUT BY A PLANE. LIGHT DIAGONAL LINES ARE SO SPACED AS TO GIVE A SHADED EFFECT.

BREAK LINES: (HEAVY)
ON SHORT BREAKS A FREEHAND LINE IS USED. ON LONG BREAKS A RULED LINE AND FREEHAND ZIG-ZAG LINES AT SPACED INTERVALS.

ADJACENT PARTS: (HEAVY)
BROKEN LINE, MADE UP OF ONE LONG AND TWO SHORT DASHES.

CUTTING PLANE: (MEDIUM) A A
A BROKEN LINE MADE UP OF ONE LONG AND TWO SHORT DASHES.

CENTER LINES: (MEDIUM)
MADE UP OF LONG AND SHORT DASH LINES.

DIMENSION & EXTENSION LINES: (LIGHT) 2"
UNBROKEN EXCEPT AT DIMENSION.

LINES OF MOTION OR ALTERNATE POSITION:
BROKEN LINE MADE UP OF LONG DASHES. (LIGHT)

NO STANDARD EXISTS FOR WEIGHT OF LINES, THE PROPER SIZE VARYING WITH DIFFERENT TYPES OF DRAWINGS. IT IS, HOWEVER, POSSIBLE TO MAINTAIN A STANDARD CONTRAST.

Figure 8.—Blueprint lines.

Most drawings use three weights or widths of lines; heavy, medium, and light. These weights may vary on different drawings, but on any one drawing there is always a noticeable difference between a heavy line and a light line, with the weight of the medium line in between. The most important lines on the drawing are the visible outlines. These are heavy lines to represent the edges and surfaces that can be seen at the angle from which the view is drawn. You wouldn't be able to identify an object without them.

To show the edges and surfaces that are behind the outer surface being viewed, hidden lines are used. These hidden lines, or invisible outlines, are represented by a medium weight line made up of short dashes.

The dimension line is a light line, unbroken except where a dimension is indicated. The length, width, or height of a dimensioned part is indicated by a number or fraction placed in the break in the line.

You won't usually find dimension lines in the view itself. To prevent dimension lines from being mistaken for lines that are part of the view, extension lines are used. These lines start $\frac{1}{16}$ inch from the outline and extend $\frac{1}{8}$ inch beyond the dimension line. They never touch the outline at any point.

Center lines are made up of long and short dashes alternately spaced. They are used to divide a drawing into equal or symmetrical parts. You will find these lines helpful in dimensioning a layout.

The alternate position line is used to show alternate position of the moving part. It is a medium broken line made up of long dashes. It can also be used to show the relation between a part and an assembly. When it is used in this manner it is often called an adjacent line. On some drawings the draftsman is cramped for space. If the whole object were drawn, it would run off the paper and a larger paper and drawing is not necessary to show the details required. Long break lines are used to tell you that the length of an object has been shortened on the print. It is a medium ruled line broken by three zigzags. It does not change the actual length given in the dimensions.

Short break lines are heavier free hand wavy lines. They are used to show the removal of an outer surface to reveal the inner structure. They are also used as a space saver to indicate a short break.

When the draftsman wants to refer you to another view so that you can see a section of the object, he will show you where that section is in relation to the object and in which direction you will be looking when you see the section, by means of a cutting plane line. A cutting plane line is a heavy broken line made up of one long and two short dashes alternately spaced.

Material that has been cut by a cutting plane is indicated by cross-section lines. These are light solid lines spaced evenly to present a shading effect.

CONVENTIONAL BREAK

A long bar or pipe that has a uniform cross-section is not always shown in its entire length. By breaking out one or more pieces and moving the ends together a larger and more readable scale can be used.

A draftsman uses different kinds of breaks to show different shapes and materials. Some of the more common conventional breaks are shown in figure 9.

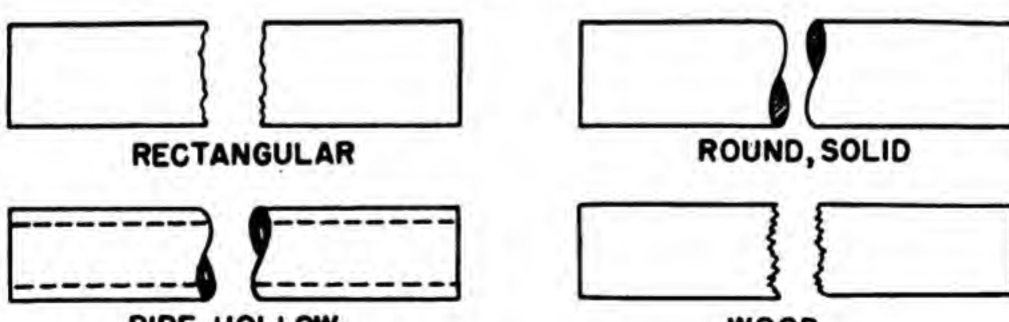


Figure 9.—Conventional breaks.

You will use the dimensions that appear on a print two ways. When you cut a piece of stock to size, you will be

following the size dimension; when you locate holes for drilling or positions for slots, you will be following location dimensions.

For small parts that have few location dimensions, continuous or accumulated dimensions are frequently used. *A* in figure 10 illustrates this type of dimension. If you follow these dimensions and make an error in cutting the stock or measuring the first hole, it will be passed on to the next measurement with the result that any errors made will accumulate.

To avoid accumulation of errors, the base-line or nonaccumulative method is used as shown in *B* and *C* of figure 10. If you make an error and cut the stock $\frac{1}{32}$-inch undersize, use the left edge as the reference edge and you won't be more than $\frac{1}{16}$-inch out at most for the last inch even if you make a plus $\frac{1}{32}$-inch error on each hole. In *C* a simplified form of base-line dimensioning is used. Use the left-hand line as the reference line exactly as described for *B*. The aircraft industry prefers this form because it takes less space on a blueprint.

In base-line dimensioning there is no way to eliminate a possible error in the last dimension. To keep the error from falling in the last dimension, a system of floating dimensioning can be used. This is illustrated in *D* of figure 10.

You will notice that the middle dimension in *D* has been omitted. The draftsman expects errors to fall within this space. Measuring the dimensions on either side of this space from the left reference edge and the right reference edge will put the error in this space.

Usually when you see a pattern of holes located around the center line, you know that another part dimensioned the same way will be fastened to it. Center-line dimensioning will help you line up the holes. Figure 10–E illustrates this method of dimensioning.

There are three holes in the first set. Notice that the draftsman is given $1\frac{5}{8}''$ as the distance from the left reference edge to the center line of the middle hole; so in making the layout from this print you would locate this hole first.

Then locate each hole on either side by measuring $\frac{3}{4}''$ from the center line of the middle hole to take care of one set of holes.

From the center line of the middle hole measure off $2\frac{1}{8}''$ to locate the center of the first hole in the second set. Then using the center of this hole measure $\frac{1}{2}''$ to locate the center of the last hole. When you lay out the other parts use the same procedure and your holes should line up.

CARE OF BLUEPRINTS

Blueprints are permanent records that can be used repeatedly if they are handled right. Here are a few simple rules to observe in using and handling blueprints.

Keep them out of strong light (especially sunlight) because exposure to strong light causes the prints to fade. Have your hands clean before you handle prints and don't spread them out on a greasy or oily work bench. Don't allow them to get wet, dirty, or grease smudged. An airplane wing is sometimes a convenient place to spread out a print.

The print should not be bent back on the folds in any manner other than the way it was delivered. Blueprint paper is brittle and will crack easily if it is folded too often or incorrectly.

Don't pencil or crayon notations on the print without proper authority. If you should be instructed to mark a blueprint, use a yellow pencil. Ordinary lead pencil does not show up on blueprint paper.

Never measure a distance directly from the print. If you cannot find a dimension on one view look for it on another view. If you still can't find it, ask your chief or someone who knows. The mechanical drawing may not have been exactly to scale and the blueprints may have stretched or shrunk. You can't afford to waste time and material by taking chances. When you are finished with a print, refold it along the original fold lines and place it in a safe place. If you won't need that particular print again, return it to the files so that it won't be lost or misplaced.

QUIZ

1. What makes a blueprint blue?
2. Why are the lines white?
3. Where do you find basic information about a print?
4. What does the zone number tell you?
5. What does a station number tell you?
6. In what order do you always refer to dimensions?
7. What are dimension limits?
8. What is a "tolerance"?
9. How many views are usually shown in an orthographic projection drawing?
10. How many different weights or width of lines are used on most drawings?
11. List the eight kinds of lines mentioned in this chapter.
12. How can you avoid the accumulation of errors?

CHAPTER 4

FABRICATION PROCEDURES

SEAMS

Of the numerous kinds of seams used in joining sheet metal, there are three common and useful types with which the Aviation Structural Mechanic should be familiar. These are the simple lap seam, the grooved seam, and the standing seam.

The simple lap seam is the least difficult to fabricate. In making this seam, the pieces of stock are merely "lapped" one over the other as shown in figure 10, and secured by either riveting or soldering, or both, the method used depending upon the nature of the job. If the seam is to be subjected to stress, it should be riveted, but if the joint is to be water- or gas-tight, soldering is called for. The allowance for a lap seam is equal to the width of the seam.

The construction of cylindrical objects—such as funnels, pipe sections, containers, marking buoys, and tanks—requires

extensive use of the grooved seam. The steps in forming this seam are shown in figure 11.

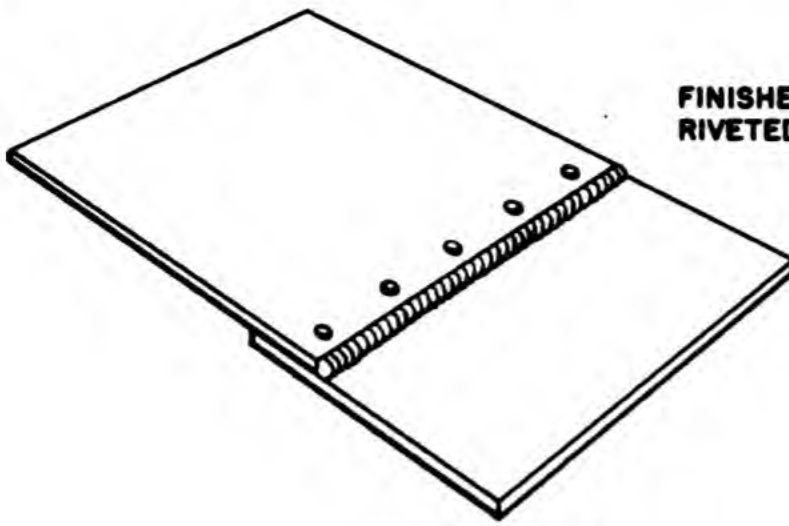


Figure 10.—Lap Seam.

The standing seam is frequently used when joining two sections or parts of an object such as the splash ring to the body of a funnel. The steps in making a standing seam are shown in figure 12. If the object has straight sides, the flanges may be turned in the bar folder, and if cylindrical, the flanges are turned with the burring machine. Notice the distribution of the allowances for the seam. Two-thirds of it is on one section, the remaining portion on the other. Sections (A) and (B) are equal and (C) is one thickness of the metal less than (A).

Figure 11.—Steps in forming a grooved seam.

A wire edge is made by wrapping metal around a piece of wire or rod, the metal being bent by hand or on a bar folder. An allowance equal to two and one-half times the diameter of the wire should be provided for the fold to receive the wire.

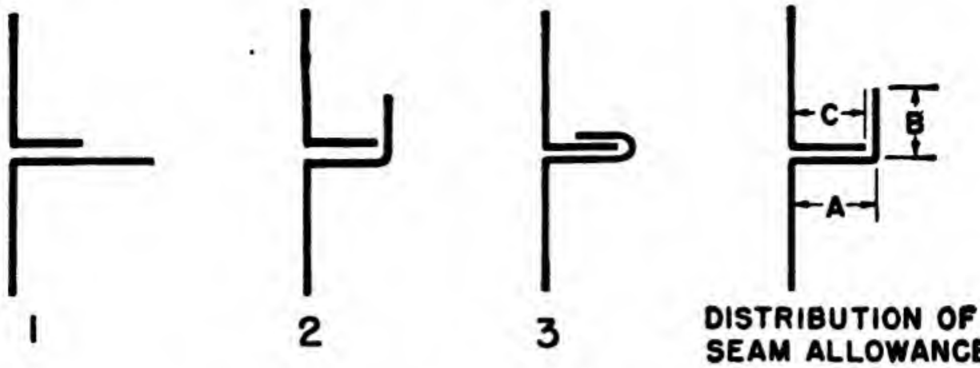


Figure 12.—Steps in forming a standing seam.

After the metal is partly bent over the wire with a mallet, the final wrapping operation may be continued either with the peen of a hammer or with a wiring machine.

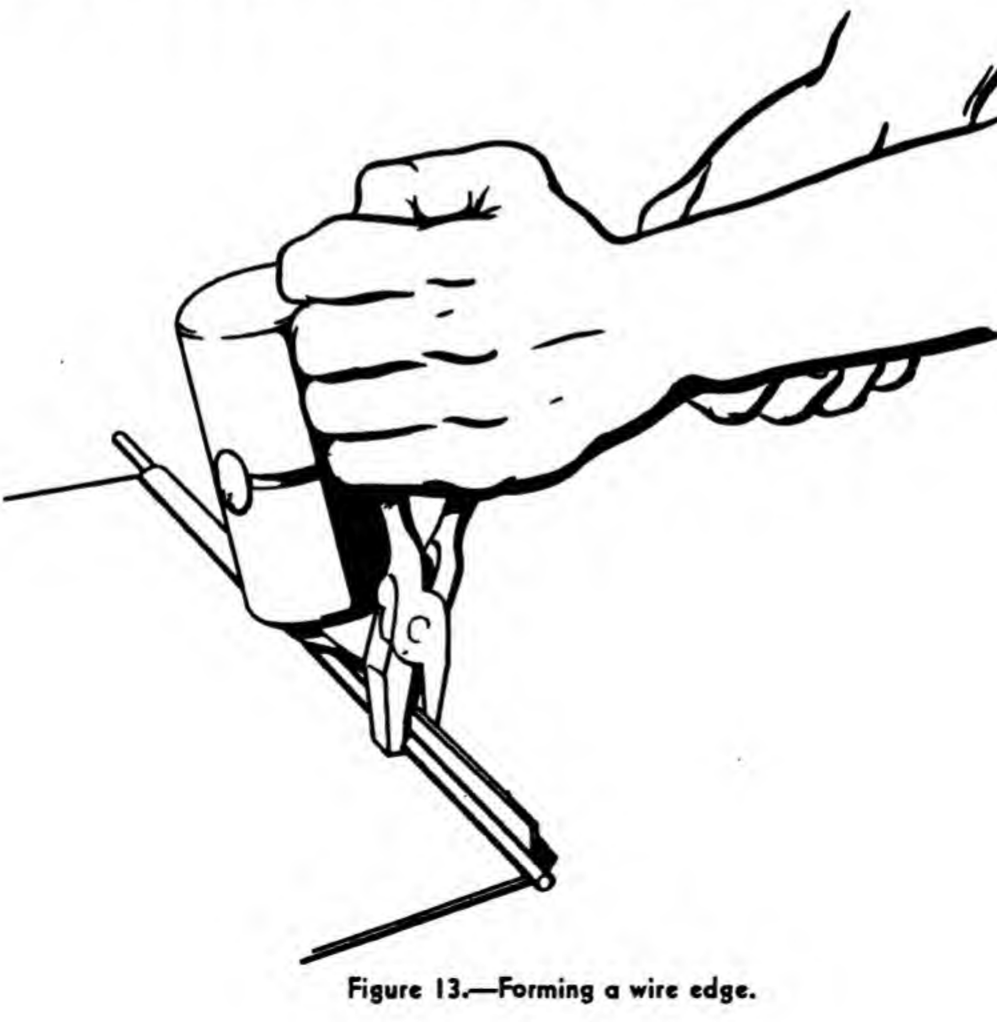


Figure 13.—Forming a wire edge.

Reinforcing edges. There are several methods used to reinforce or stiffen the edges of sheet metal objects. One method is to form either a single or double hem, and another is to reinforce the edge with wire or rod.

A **single hem** is made by simply turning the metal back on itself once. A **double hem** is formed in the same manner except that the metal is folded twice instead of once, as shown in figure 14.

Figure 14.—Single and double hems.

HAND BENDING OF SHEET METAL

Bends or folds can be made in sheet metal by using stakes, blocks of wood, angle iron, a vise, or the edge of a bench. These various methods of bending may be used when machines are not available for the formation of plain bends or folds, single and double hems, edges for grooved seams, and edges for wiring.

The forming of metal by hand or with the use of stakes or blocks requires a knowledge of HOW sheet metal works. A good worker will bend the metal a little at a time to eliminate the possibility of buckling and stretching. He is also very careful to prevent kinks and marks from appearing on the finished surface of his work because of improper forming or from using the wrong tool.

Bending Over Stakes

The contour of objects whose sides are cylindrical, conical, or straight may be formed over stakes. Working the metal a little at a time will avoid wrinkles and cracks. In most instances, a wooden or other soft-faced mallet should be used to avoid marking the metal. Figure 15 illustrates three methods of forming metal by hand over stakes.

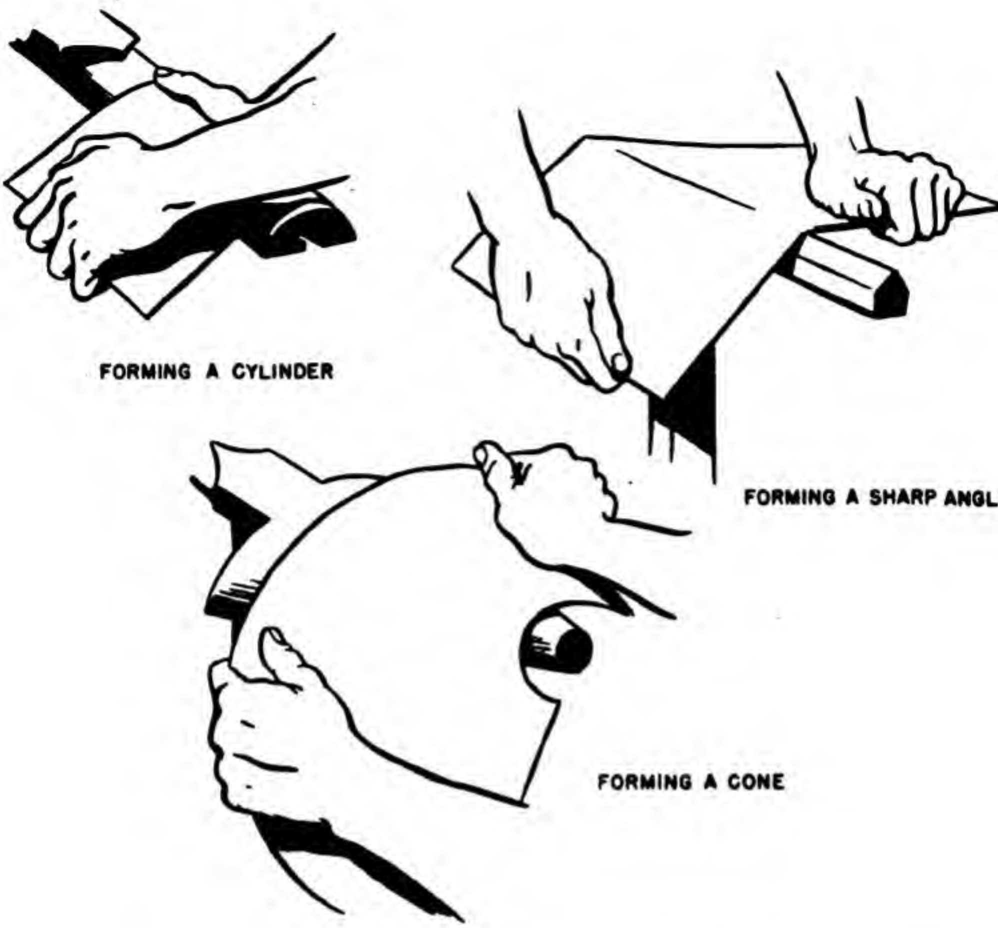


Figure 15.—Three methods of forming metal by hand over stakes.

Bending in a Vise

Small pieces of sheet metal may be bent by being placed between a set of wooden blocks which are clamped in a vise. The stock protruding above the edges of the blocks is hammered over with a mallet. If the operation calls for a bend of a specified radius or angle, it will be necessary to file the arris or corner of one of the blocks to the desired radius, or plane the edge to the desired angle.

Bending With Blocks

In some cases, metal may be bent with the hands by working it over the edges of a bench or between two wooden or metal blocks held together with clamps. In either case, the

procedure is much the same as for bending in a vise. The position of the bend is located and marked on the stock, and the line along which the bend is to be made is placed over the edge of the bench top or piece of angle iron. The blocks are secured with **C** clamps, and the bend is formed by hammering the stock with a wooden mallet. This procedure is shown in figure 16.

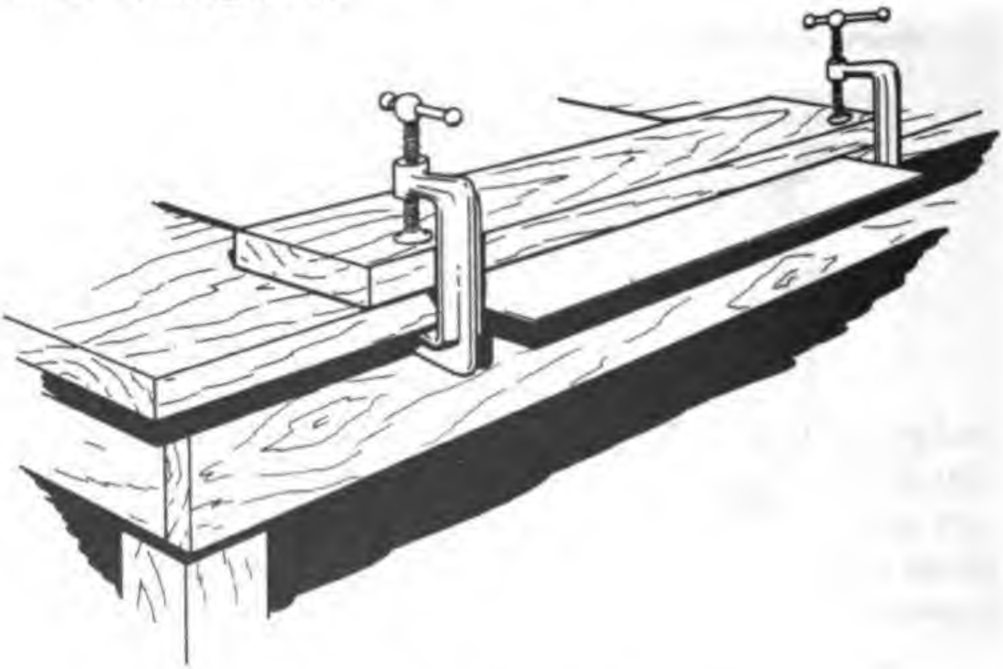


Figure 16.—Block-bending procedure.

BURRING

Burring is perhaps the most difficult operation performed on a rotary machine, although adherence to specific directions and careful practice will develop the necessary skill. The principles involved can best be explained by following the procedure for turning an edge on a disc for a snap bottom.

Adjust and align the rolls so that the top roll fits down over the shoulder of the lower roll. The distance between the inside face of the top roll and the shoulder on the lower roll should be equal to the thickness of the metal on which the edge is to be turned. Set the guide, in this case, for a scant 1/8 inch in from the inside of the back face of the top roll.

Place the disc so that its face rests on the two edges of

the lower roll, with its edge against the guide as shown in (A) of figure 17. Lower the top roll until it barely grips the metal.

Place the palm of the left hand against the guide, grip the disc between the thumb and index finger, and turn the crank slowly. Hold the disc firmly against the guide by applying pressure just in front of the rolls. The "track" must be properly made during the first revolution, after which the speed of the crank is increased while the disc is gradually raised until the burr is turned. Figure 17 (B) illustrates this step. Remove the disc by raising the top roll.

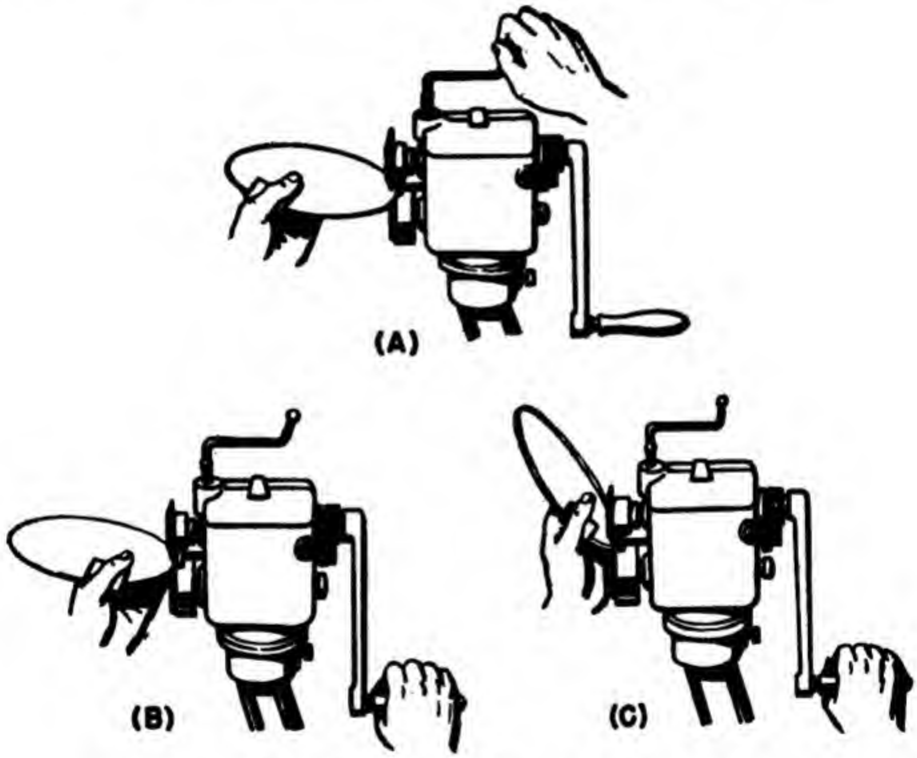


Figure 17.—Steps in burring operation.

TURNING

Turning is not a difficult operation, and the following description should adequately explain the procedure for turning a curved flange for a wire edge.

Adjust the rolls, aligning them so that the top roll is centered in the groove of the lower roll. Set the guide as determined by the diameter of the wire. Place the metal between the rolls so that it presses against the guide, and

lower the top roll until it grips the metal. Turn the crank slowly, holding the metal so that it will feed into the rolls while continuing to press against the guide. After the first revolution, gradually raise the metal until it touches the outer face of the top roll. Remove the stock by raising the top roll.

WIRING

The wiring machine is easy to operate, as the following steps will demonstrate.

Adjust the rolls so that the top roll is directly above the point on the lower roll where the beveled and flat surfaces meet, as shown in (A) of figure 18. Adjust the guide to the first position shown in (B) of figure 18, then bring the top roll down so that it will turn the edge of the metal as illustrated in (C) of figure 18. Remove the stock from the machine by raising the top roll.

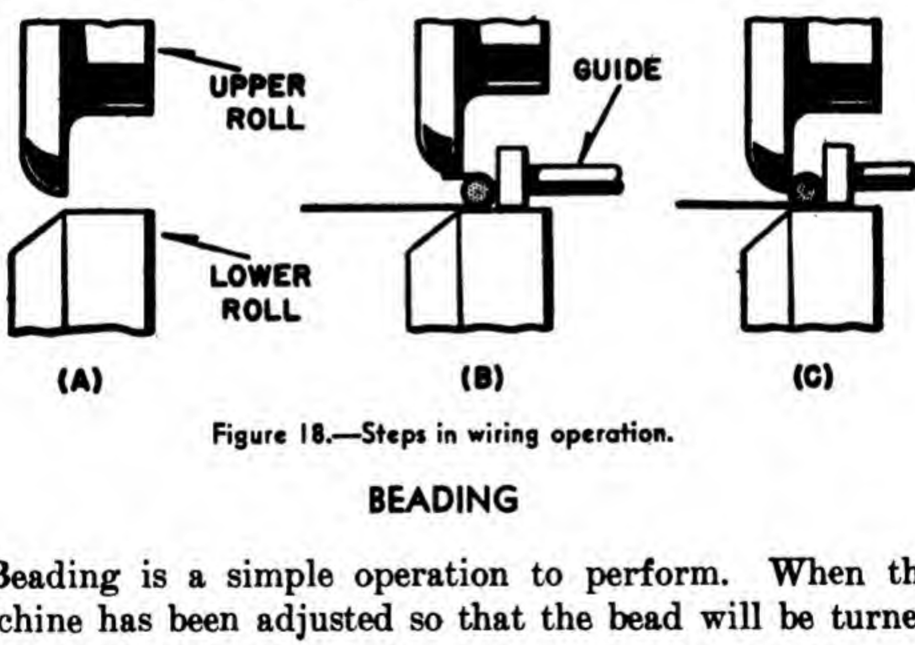


Figure 18.—Steps in wiring operation.

BEADING

Beading is a simple operation to perform. When the machine has been adjusted so that the bead will be turned in the desired position, place the stock between the rolls and bring the top roll down with sufficient pressure to indent the metal slightly. Make the first revolution so that the "track" will be properly located, holding the stock firmly against the guide. Repeat this procedure until the bead reaches the desired depth.

ROLLING SHEET METAL

The slip-roll forming machine requires considerable experience to operate in order to make well-formed work. Experiment alone will determine the exact distance the rolls should be separated to form the required curvature. The following outline will explain the procedure for operation of this machine.

First lock the top roll in position and then adjust the lower front roll parallel to it, the distance between the two being such that the rolls will grip the metal. This adjustment is made with the knurled thumb screws located beneath the housing at either end of the machine.

Insert the sheet between the rolls from the front of the machine, and start the metal by turning the handle as shown in (A) of figure 19. When the edge of the stock is caught between the two front rolls, raise the sheet with the left hand to make the starting bend, as may be seen in (B), then roll the sheet through the machine as shown in (C). If the curvature is either too small or too large, bring the

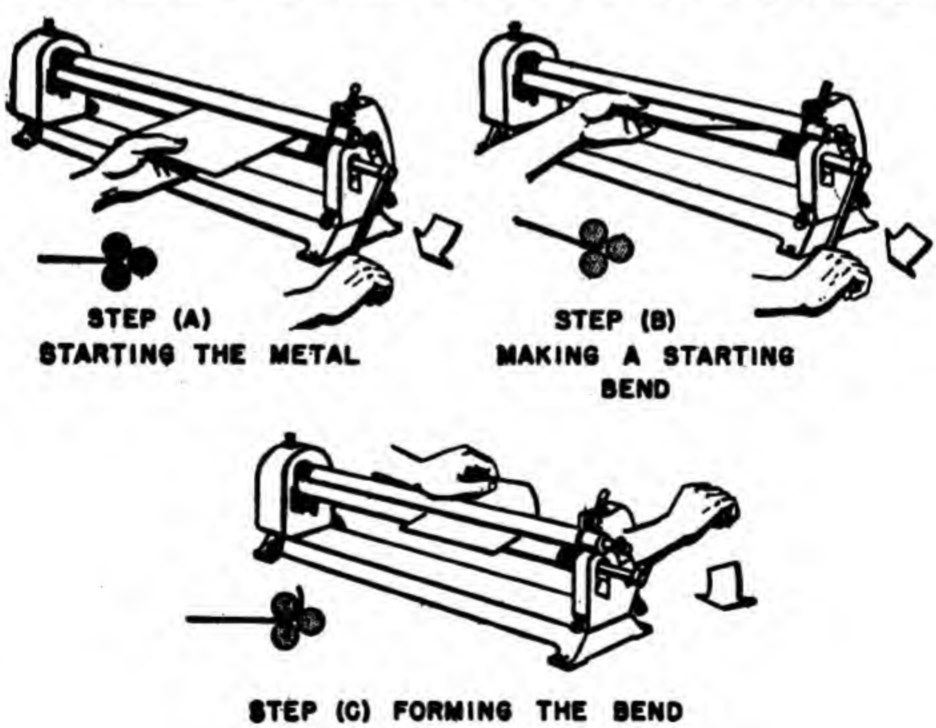


Figure 19.—Steps in rolling operation.

sheet back to its starting position by reversing the direction of the handle. Readjust the rear roll and run the sheet through again, repeating this procedure until the required curvature is obtained. Remove the piece by raising the top roll.

Rolling Tapered Shapes

To roll a tapered shape, set the rear roll so that the rolls on one end are closer together than on the opposite end, as shown in figure 20 (A). Insert the sheet, and as the handle is turned, hold it back with the left hand so that the lines of the pattern AA, BB, and CC pass through the center of the upper roll, as shown in (B) of figure 20.

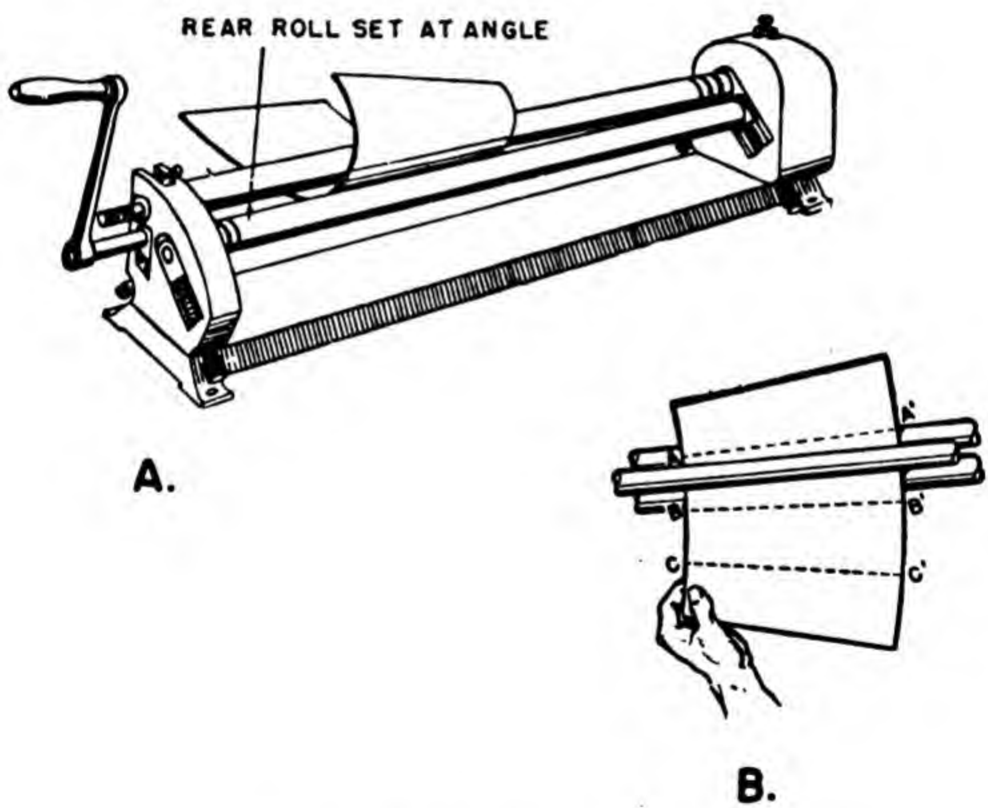


Figure 20.—Rolling a tapered shape.

An alternate method is to roll the sheet partly through the machine and withdraw the short end until AA is under the center of the top roll, then roll the sheet farther and pull it

back until BB is under the rolls. This is repeated until the entire sheet has passed through the rolls.

Rolling a Cylinder With a Wire Edge

To perform this operation, set the machine so that the distance between the upper and lower rolls is greater at the wire end than at the opposite end. Insert the sheet between the rolls from the front end of the machine, placing the wired edge into the proper size groove. The actual operation of rolling is similar to that of forming a flat sheet.

MACHINE-BENDING OF SHEET METAL

One of the most common operations in sheet metal work is the folding of metal. To fold a hem or turn a lock, there must be some means of holding the metal firmly so that the desired shape can be made where it is needed. Two types of machines are used for this purpose—those of which the width of the fold is limited, and those on which there is no limit. The former are known as FOLDERS, the latter as BRAKES.

Bar Folder Operation

The actual operation of a bar folder is very simple. When the thumb screw has been adjusted to the specified width of the fold, turn the adjusting lever at the back of the machine for the desired bend. Then insert the metal under the folding blade as far as it will go.

Hold the metal firmly in place with one hand, grasp the handle with the other, and pull forward until the desired fold is made. The various positions in this bending procedure are shown in (A) and (B) of figure 21. The hem may be flattened as illustrated in (C).

Cornice Brake Operation

To operate the cornice brake for the formation of a simple bend, insert the sheet between the upper jaw and the bed, and

clamp it in place by pulling the lever. The folding wing is then raised to produce the bend, the distance this wing is moved determining the angle of the bend.

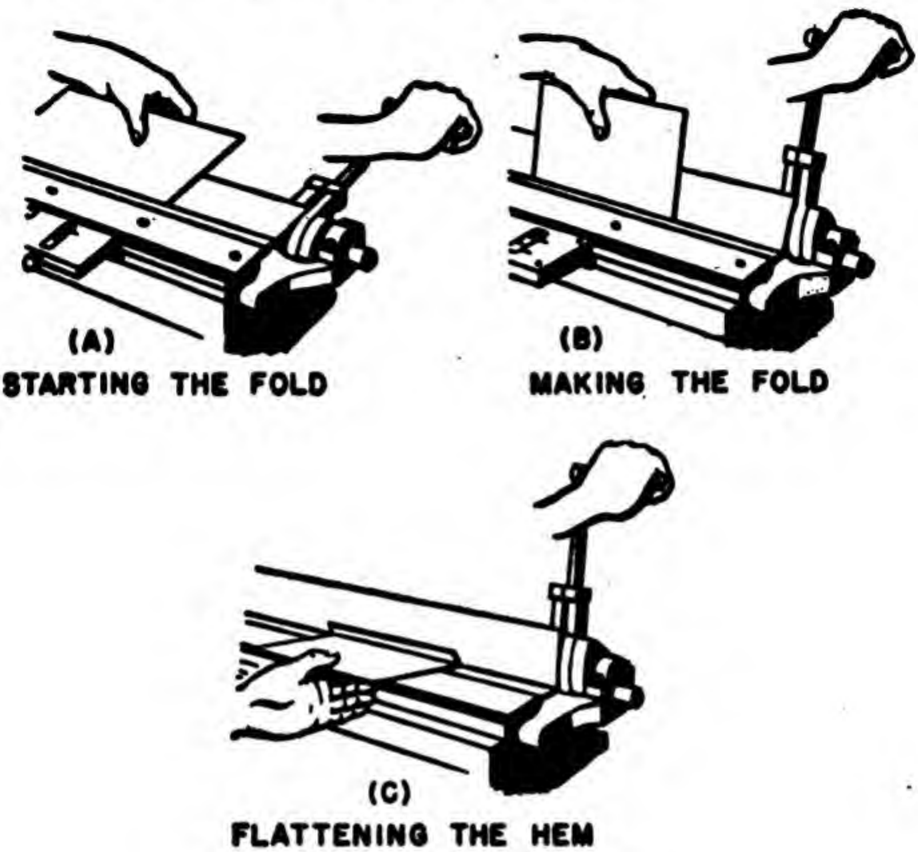


Figure 21.—Bar folder operation.

Box and Pan Brake Operation

If bending machines are not used correctly, the time and work involved in computing bend allowance, as well as the metal itself, is wasted. Once the metal is bent, it is practically impossible to flatten it out and rebend it, especially heat-treated aluminum alloys. Before bending any work demanding accurate bend radius and definite leg length, the setting of the brake should be checked with a piece of scrap. The point where the metal is placed in the brake, with relation to the jaws, will determine whether or not the leg length will be correct.

When the bend allowance is computed and marked off, the metal is inserted into the brake and the bend line is placed directly under the upper jaw as shown in figure 22.

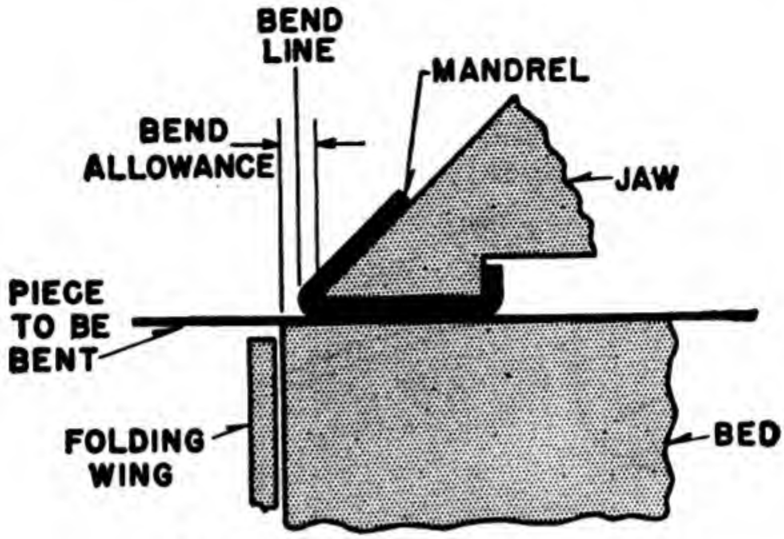


Figure 22.—Box and pan brake operation.

BEND ALLOWANCE

In making aircraft repairs, it is often necessary to bend flanges on flat sheets to form channels and various shaped angles. The Aviation Structural Mechanic will find that a knowledge of the principles and application of bend allowance is invaluable and that much time and material will be saved if these principles and applications are used rather than trial and error methods.

Aluminum alloy which has been formed to a sharp angle is not as strong as when it has been shaped to a rounded corner, as the sharply bent piece will have the stresses concentrated at the bend. Even though aluminum alloys are malleable, they will crack if bent too sharply. Since aircraft design places such great emphasis on the strength of the various parts, the accepted practice in construction and repair is to form flanges or bends with a radius that experience has shown will leave the bent sheet as strong as the original flat sheet.

Aluminum alloy of any thickness may be bent cold, pro-

vided it is done over a properly rounded corner. This curvature at the bend is referred to as the BEND RADIUS. It is the inside radius of the curve, as shown in figure 23. The required radius varies both with the grade and the thickness of the alloy. No specific value can be set up for the radius at which a sheet of a given material and thickness must be bent. There are, however, minimum radii which are generally accepted. Taken from the bend allowance table universally used in the aircraft industry, these radii are shown in chart 1.

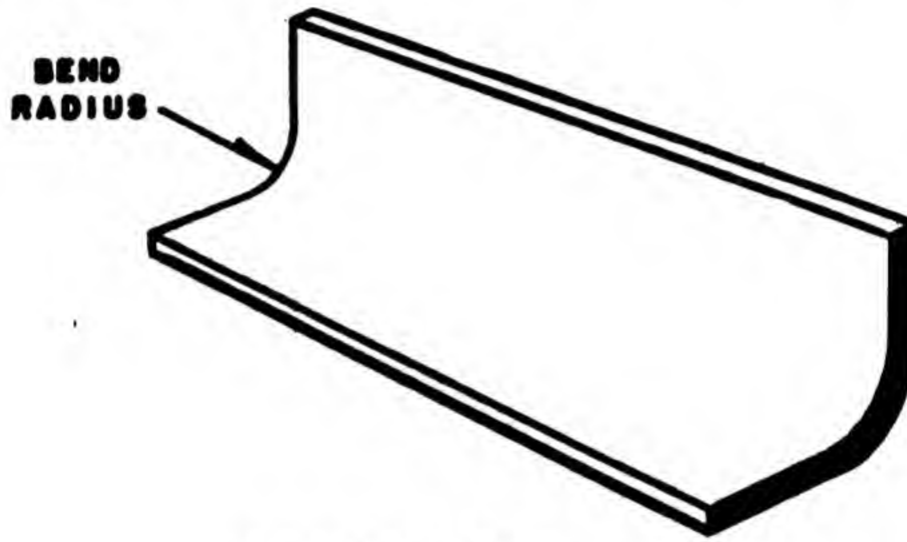


Figure 23.—Bend radius.

RADII REQUIRED FOR 90° BENDS IN ALUMINUM ALLOY

Approximate Thickness

Alloy	0.020	0.025	0.028	0.032	0.040	0.045	0.051	0.057	0.064	0.072	0.081	0.128
17SO.. 24SO..	0	1/32	1/32	1/32	1/16	1/16	1/16	3/32	3/32	1/8	1/8	7/32
17ST..	1/32	1/16	1/16	1/16	3/32	1/8	1/8	5/32	5/32	5/32	1/4	5/16
24ST..	3/32	1/8	1/8	1/8	5/32	3/16	3/16	3/16	3/16	7/32	5/16	1/2
24SRT	3/32	1/8	1/8	1/8	5/32	3/16	3/16	1/4	1/4	9/32	7/16	5/8

Chart 1.—Minimum radii chart.

In addition to using the proper bend radius, the actual amount of material used to form the bend must be known if accurate results are to be obtained. The amount of material which is actually used in making the bend is known as BEND ALLOWANCE, illustrated in figure 24. Theoretically, the bend allowance for a 90° bend would be equal to one-fourth of the circumference of a circle whose radius is equal to the bend radius plus one-half the thickness of the metal. This is illustrated in figure 25.

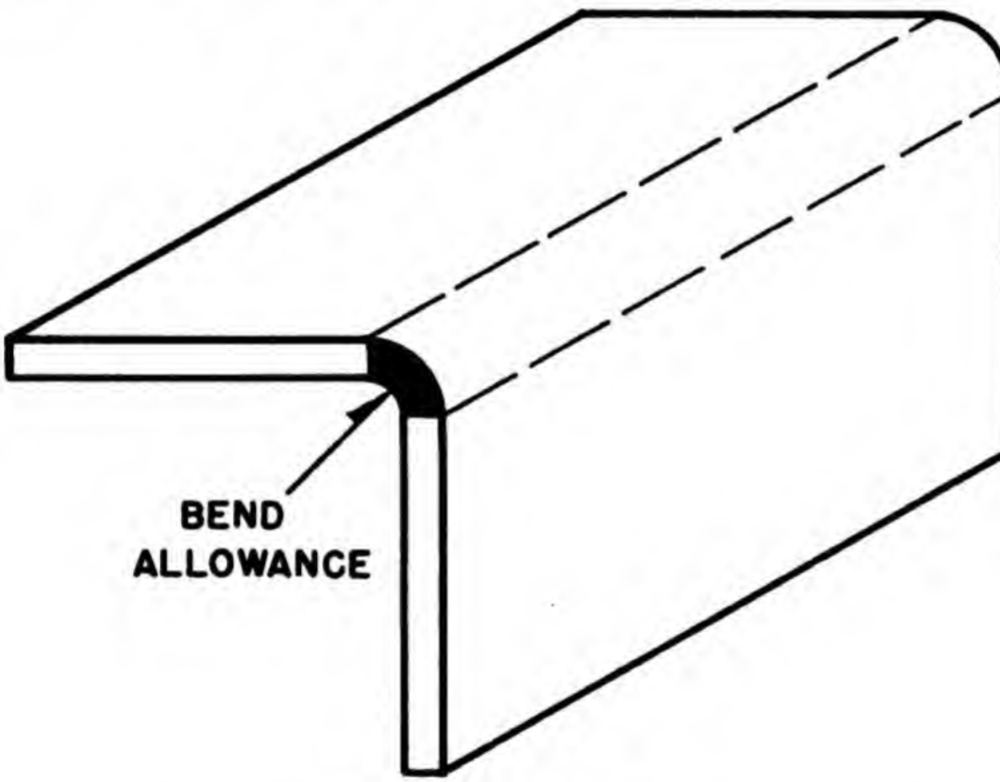


Figure 24.—Bend allowance.

For bends greater or less than 90°, the bend allowance would be more or less, respectively, than one-fourth of the circumference.

In actual practice, however, bend allowance does not work out so simply. The bend allowance is affected by the shrinking and stretching of the metal at the bend. This varies with the different bend radii, the thicknesses of metal used, and the type and temper of alloys used. Aircraft engineers

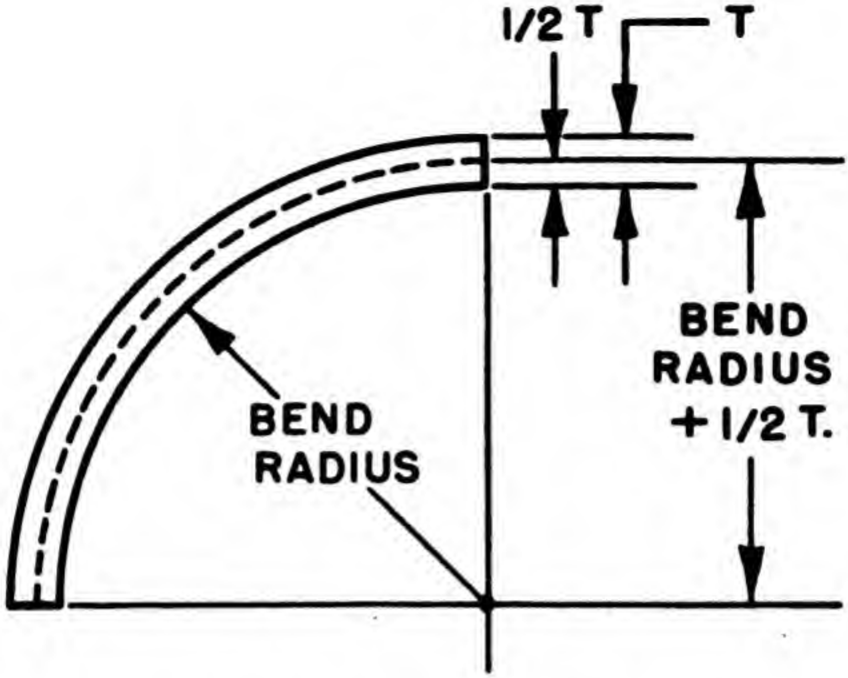


Figure 25.—Bend radius allowances.

have developed methods for determining the bend allowance and have found, by actual bending, the effect of the factors just mentioned. Before discussing methods of determining bend allowances, we must first understand what happens when metal is bent and why the amount of material required for the bend varies. Figure 26 illustrates clearly that the amount of material required for any rounded corner (A) will be less than the material required for a square corner (B).

When metal is bent, the outside of the bend is stretched or lengthened, while the material on the inside is forced to shrink or shorten. The metal along a line through the middle of the thickness of the sheet is a neutral zone, where neither shrinking nor stretching occurs.

This line occupies the same length when bent as a straight line, indicating that the bend allowance is figured along the neutral axis, as shown in figure 27.

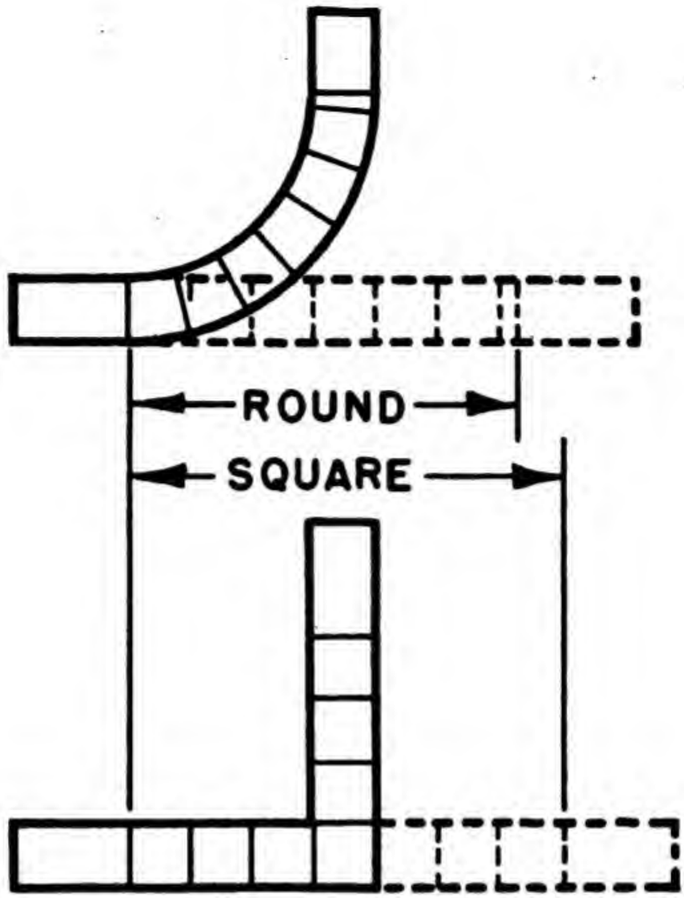


Figure 26.—Variations in quantity of material required for round and square corners.

Knowing the bend allowance required for a bend is of value only if such knowledge is applied to the actual job of figuring the amount of metal needed. The length of material required includes all the flat and curved portions. After the length of these parts has been figured, a flat pattern layout is drawn either on paper or on the metal to be used.

BEND ALLOWANCE TERMS

Planning the flat layout of a job involves the use of terms for the flat and curved portions and for various lines that are either the divisions between bent and straight portions, or the lines from which measurements are taken. These

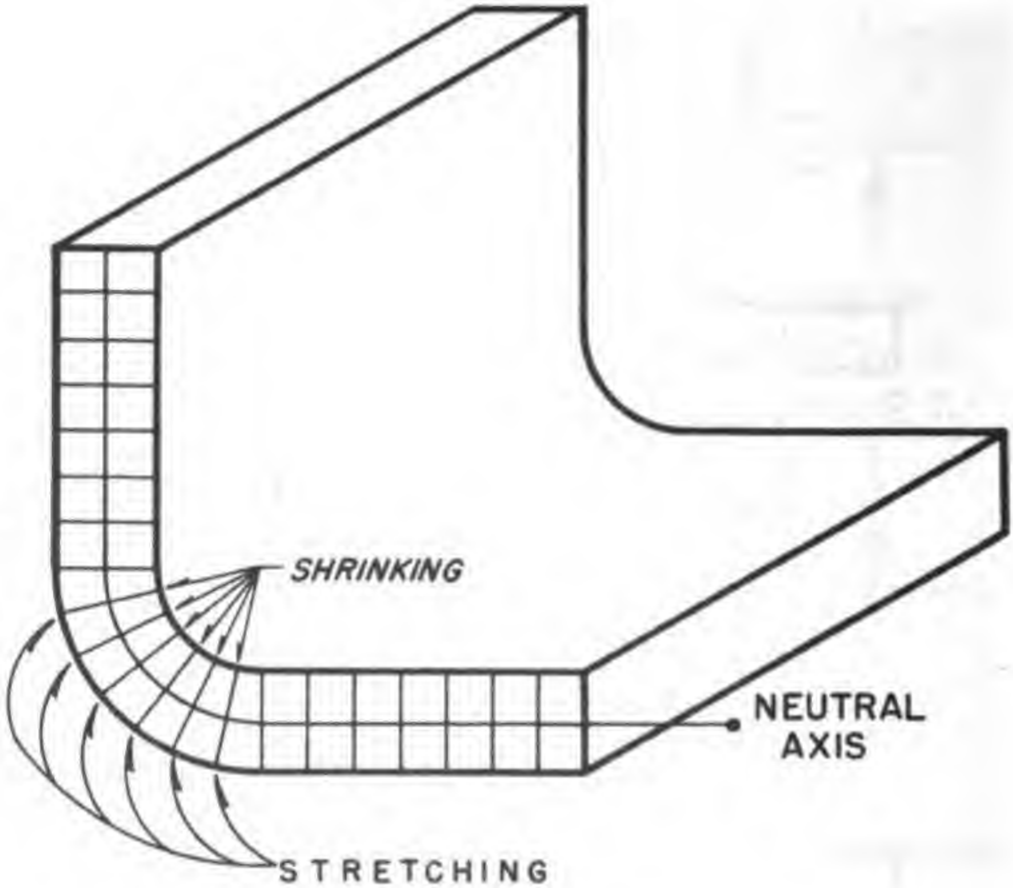


Figure 27.—Estimate of bend allowance.

terms, illustrated in figure 28, must be understood if they are to be used properly in calculating bend allowance and setback.

The BASE MEASUREMENT is the outside or over-all dimension of a part. Aircraft drawings furnish dimensions of parts by the outside or base measurement.

The BEND TANGENT lines are those indicating where the bend begins and ends.

The REFERENCE LINE is the line which would be formed at the outside corner if the metal were bent without a radius.

The SETBACK refers to the distance from the bend tangent line to the reference line. The setback must be figured with the aid of the K table, in chart 2.

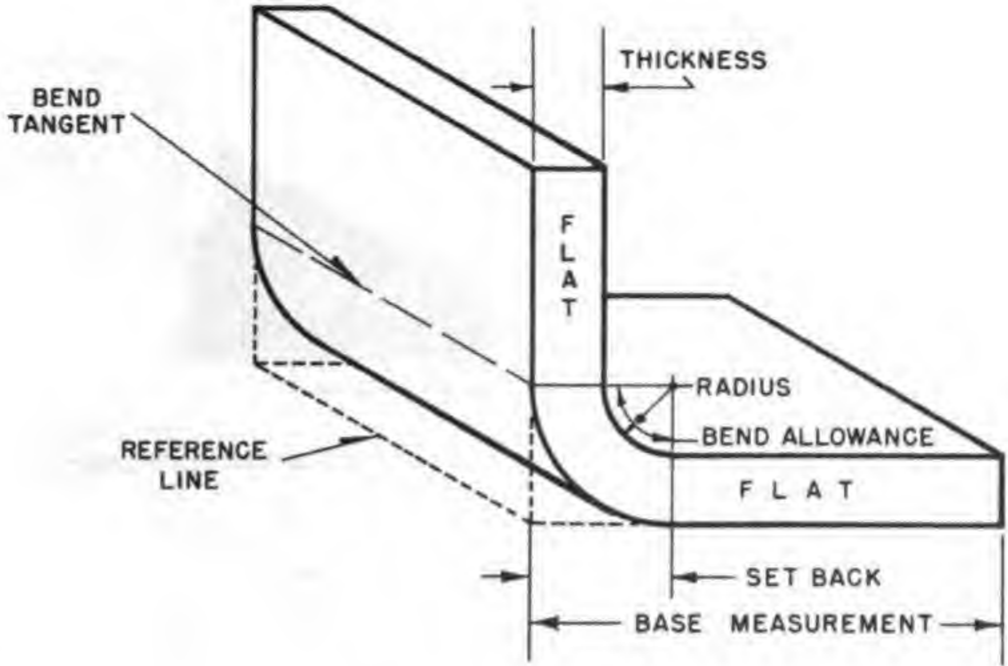


Figure 28.—Bend allowance terms.

The FLAT is the portion of the job which is not bent. In each leg, it is equal to the base measurement minus the setback.

The BEND ALLOWANCE is the amount of material consumed in the bend.

SIMPLE FLAT LAYOUT METHOD

Figure 29 illustrates an accurate method of making the flat layout which has one or two 90° bends. This method may be used for the majority of aircraft fabrication involving bending. It is applicable to only those 90° bends whose radius is equal to approximately one, two, or three times the thickness of the material. For example, where R equals $\frac{3}{32}$ (0.0937), and t equals 0.051, R equals $2t$ approximately. In using this method, the end of the sheet closest to the bend line must be inserted in the brake. The distance the bend line is located from the end of the sheet is equal to the inside height of the flange or leg.

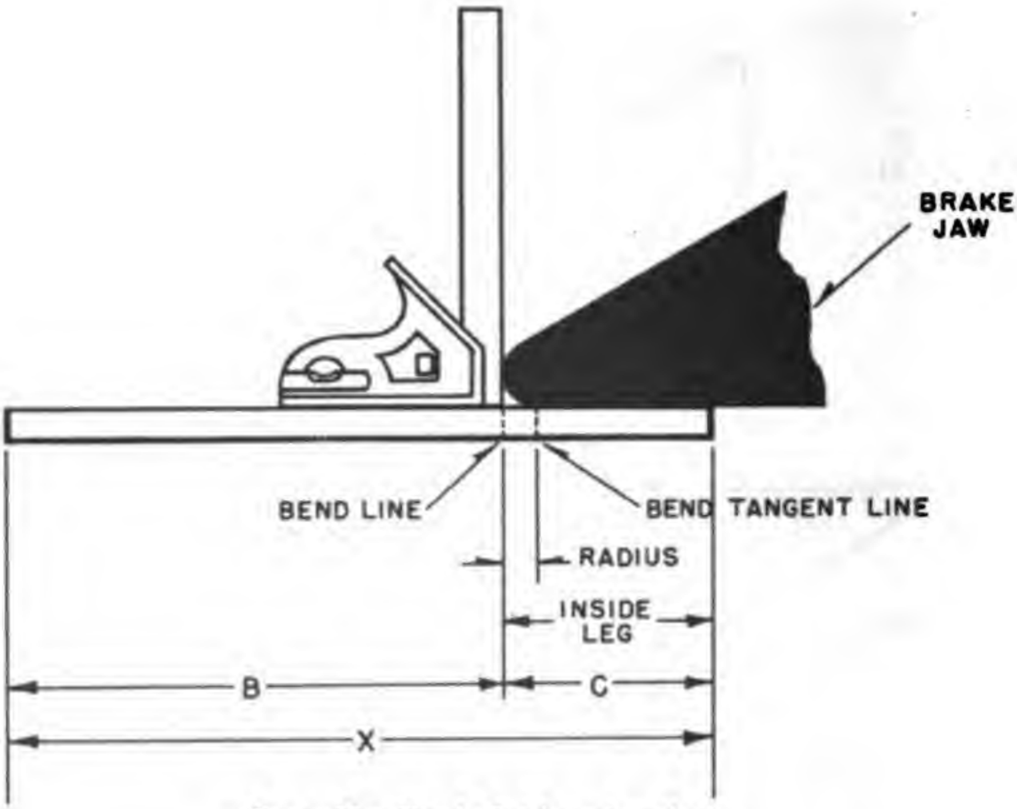


Figure 29.—Simple flat layout method.

SIMPLE FLAT LAYOUT METHOD EXAMPLE

Figure 30 illustrates the dimensions for a flanged job which can be laid out by the above method.

$$R=0.125 \text{ (i. e., } R=3t)$$

$$t=0.040$$

1. Determine inside dimensions.
   Inside height $=1.000-t$.
   Inside height $=1.000-0.040$.
   Inside height $=0.960$.
   Inside width $=3.000-2t$.
   Inside width $=3.000-0.080$.
   Inside width $=2.920$.
2. Determine over-all length, as shown in figure 75.
   Over-all length $=0.960+0.960+2.920-2\ (0.040\div 2)$.
   Over-all length $=4.80$ or $4^{51}/_{64}$.

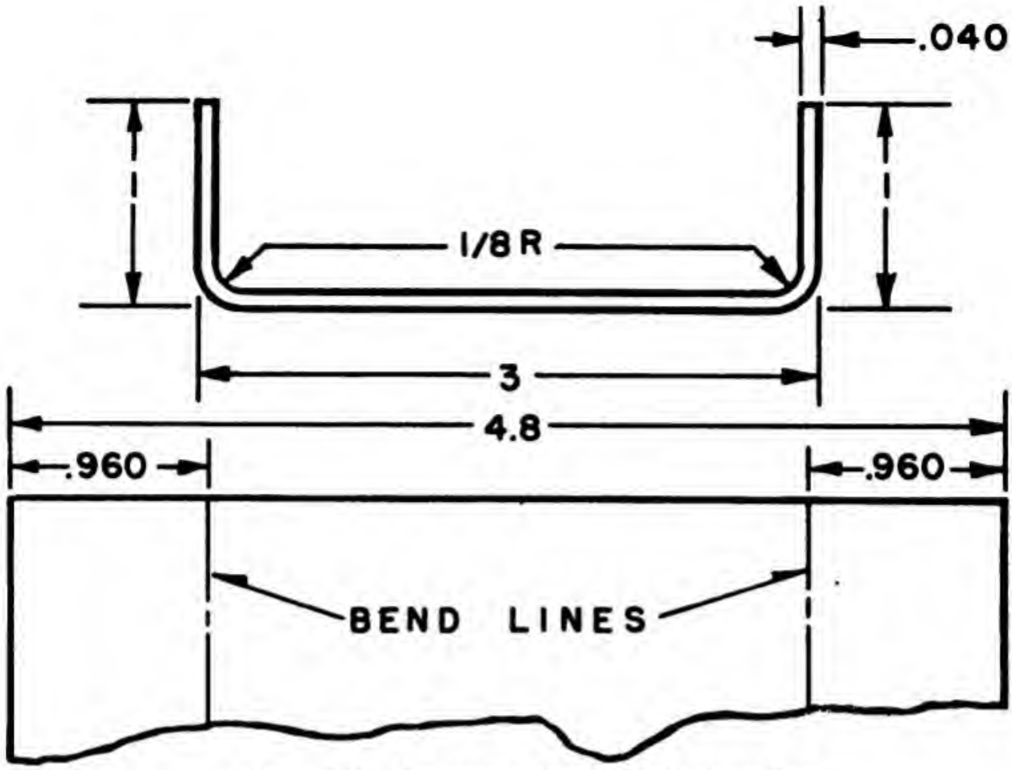


Figure 30.—Dimensions for flanged fabrication.

3. Each bend is made by inserting the end of the metal under the jaw of the brake so that the bend line—which has been marked on the sheet with a soft-lead pencil—will be directly under the nose of the brake, as demonstrated in figure 29. The bend line is 0.960 from the end of the sheet, as shown in figure 30.

FORMULA METHOD OF FLAT LAYOUT

As the name implies, the formula method of flat layout necessitates the use of the bend allowance and the setback formula when making a layout containing one, two, or more bends. The bend allowance must be determined in order to find the amount of material used in each bend, and the setback must be determined to locate the beginning of the bend.

The advantage of the formula method of layout over the simple method just discussed is its greater degree of accuracy. The formula method may be used for the flat layout of parts with any number and kinds of bends.

Bend Allowance Formula

Theoretically, the amount of material required for a 90° bend could be figured as the circumference of a quarter of a circle; but in actual practice, this is inaccurate due to the variation in physical properties of different metals. Some accurate basis must be used to determine the bend allowance for various bends. Aircraft engineers have worked out a formula based on numerous experiments with actual bends on metal. This formula can be used to determine the bend allowance required for different bends from 1° to 180° This bend allowance formula with an example is given in figure 31.

BEND ALLOWANCE FORMULA B.A. = (.01743 X R) + (.0078 X t) X N	
Formula in Use	Example
B.A. = (.01743 X R) + (.0078 X t) X N B.A. = (.01743 X .1875) + (.0078 X .040) X 35° B.A. = .003268 + .00031 X 35° B.A. .01418	N=35° t=.040 R=.1875

Figure 31.—Bend allowance formula.

The letters used in the bend allowance and the setback formula are explained as follows:

R—desired bend radius.

t—thickness of material.

N—number of degrees which the material will be bent.

Setback

To accurately make the flat layout, not only must the bend allowance for each bend be determined, but also the length of these flat portions between the curves. In order to determine the length of these flats, the setback for each bend must be found and subtracted from the base measurement.

The K table, shown in chart 2, gives the figures by which the setback for all degrees of bend can be figured. By multiplying the figure given in chart 2—which is known as constant, K, by $R+t$ — the distance from the reference line to the bend tangent line (setback) is obtained. Figure 32 illustrates the setback formula and its use.

SETBACK FORMULA SETBACK = K X (R + T)	
Formula in Use	Example
Setback = K(R + T) Setback = .31530 X (.1875 + .040) Setback = .017173	N = 35° T = .040 R = .1875 K (From Table) .31530

Figure 32.—Setback formula.

SETBACK FORMULA APPLICATION

To illustrate the use of the bend allowance and setback formulae in figuring the amount of material needed for the flat layout, and locating the bends, a few typical problems are worked out. For a job involving two 90° bends, we will use the problem previously used as an example for the simple flat layout method. The comparative accuracy of the simple method for this type of bend will be made evident. Figure 33 shows the problem in detail.

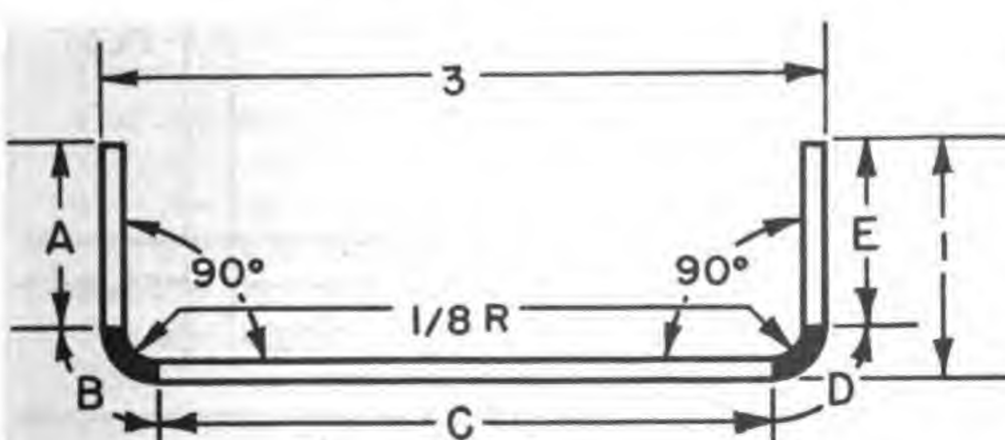


Figure 33.—Setback formula problem.

Procedure

1. Determine setback.
   Setback $= K(R+t)$.
   Setback $= 1(0.125+0.040)$.
   Setback $= 0.165$ or $^{11}/_{64}$.
2. Determine length of all flats.
   Flats A and E = Base measurement—setback.
   Flats A and $E = 1$ inch $- 0.165$.
   Flats A and $E = 0.835$ or $^{53}/_{64}$.
   Flat C = Base measurement $- 2 \times$ setback.
   Flat $C = 3$ inches $- 2(0.165)$.
   Flat $C = 3$ inches $- 0.330$.
   Flat $C = 2.670$ or $2^{43}/_{64}$.
3. Determine bend allowance for all bends (at B and D).
   $B.A. = (0.01743\ R) + (0.0078\ t) \times N$.
   $B.A. = (0.01743 \times 0.125) + (0.0078 \times 0.040) \times 90°$.
   $B.A. = 0.2242$ or $^{7}/_{32}$.
4. Make the layout as shown in figure 34.
   Total length $= {}^{53}/_{64} + {}^{7}/_{32} + 2^{43}/_{64} + {}^{7}/_{32} + {}^{53}/_{64}$.
   Total length $= 4.788$ (as compared to 4.800 or $4^{49}/_{64}$ by the simple method).

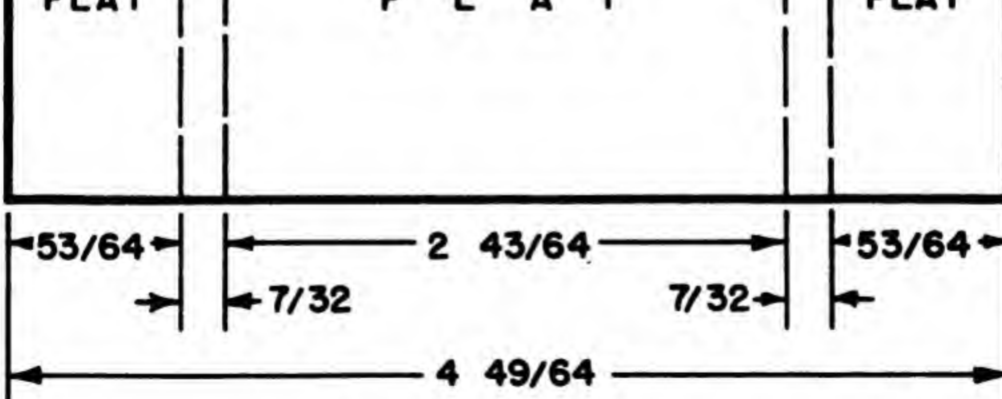


Figure 34.—Setback layout.

The following outline lists the procedure for determining the flat layout for a job with open and closed angles. Figure 35 illustrates this procedure.

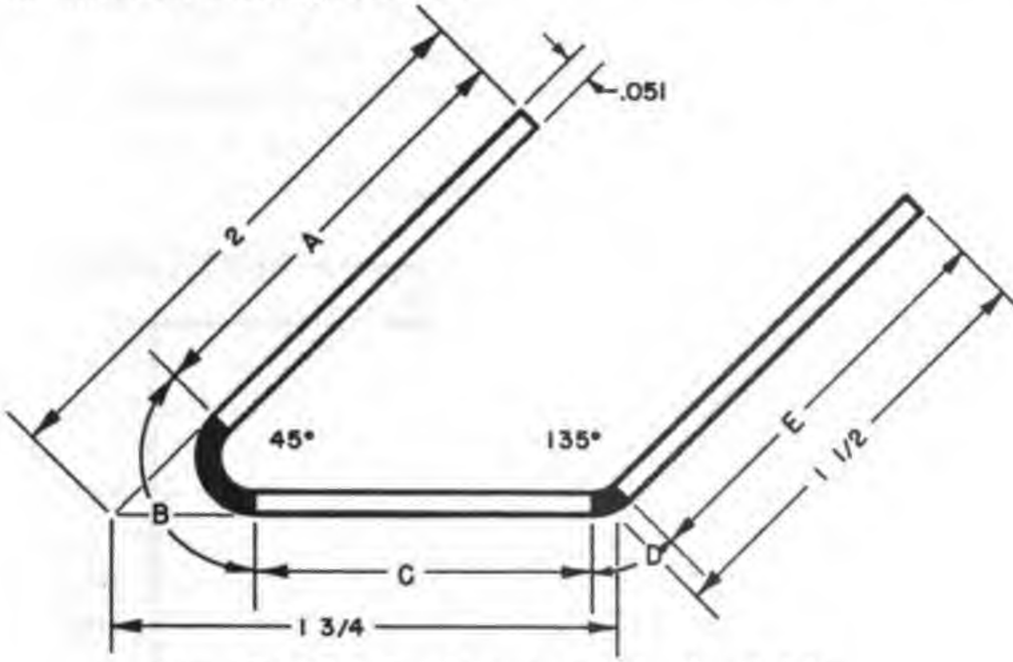


Figure 35.—Procedure for open- and closed-angle job.

Procedure

1. Determine setback.
   Setback at $B = K\ (R+t)$.
   Setback at $B = 2.4142\ (\frac{5}{32} + 0.051)$.
   Setback at $B = 0.499$ or $\frac{1}{2}$.
   Setback at $D = K\ (R+t)$.
   Setback at $D = 0.4142\ (\frac{5}{32} + 0.051)$.
   Setback at $D = 0.0857$ or $\frac{5}{64}$.
2. Determine length of all flats.
   Flat A = Base measurement—setback at B.
   Flat $A = 2$ inches $- \frac{1}{2}$.
   Flat $A = 1\frac{1}{2}$.
   Flat E = Base measurement—setback at D.
   Flat $E = 1\frac{1}{2} - \frac{5}{64}$.
   Flat $E = 1\frac{27}{64}$.
   Flat C = Base measurement—setback $B + D$.
   Flat $C = 1\frac{3}{4} - (\frac{5}{64} + \frac{1}{2})$.
   Flat $C = 1\frac{11}{64}$.

3. Determine bend allowance for all bends.

$B.A.$ at B $(0.01743\ R) + (0.0078\ t) \times N$.

$B.A.$ at B $(0.01743 \times 0.156) + (0.0078 \times 0.051) \times 135°$.

$B.A.$ at B (0.4207 or $^{27}/_{64}$).

$B.A.$ at D $(0.01743\ R) + (0.0078\ t) \times N$.

$B.A.$ at D $(0.09743 \times 0.156) + (0.0078 \times 0.051) \times 45°$.

$B.A.$ at D 0.1402 or $^{9}/_{64}$.

4. Make the layout as shown in figure 36.

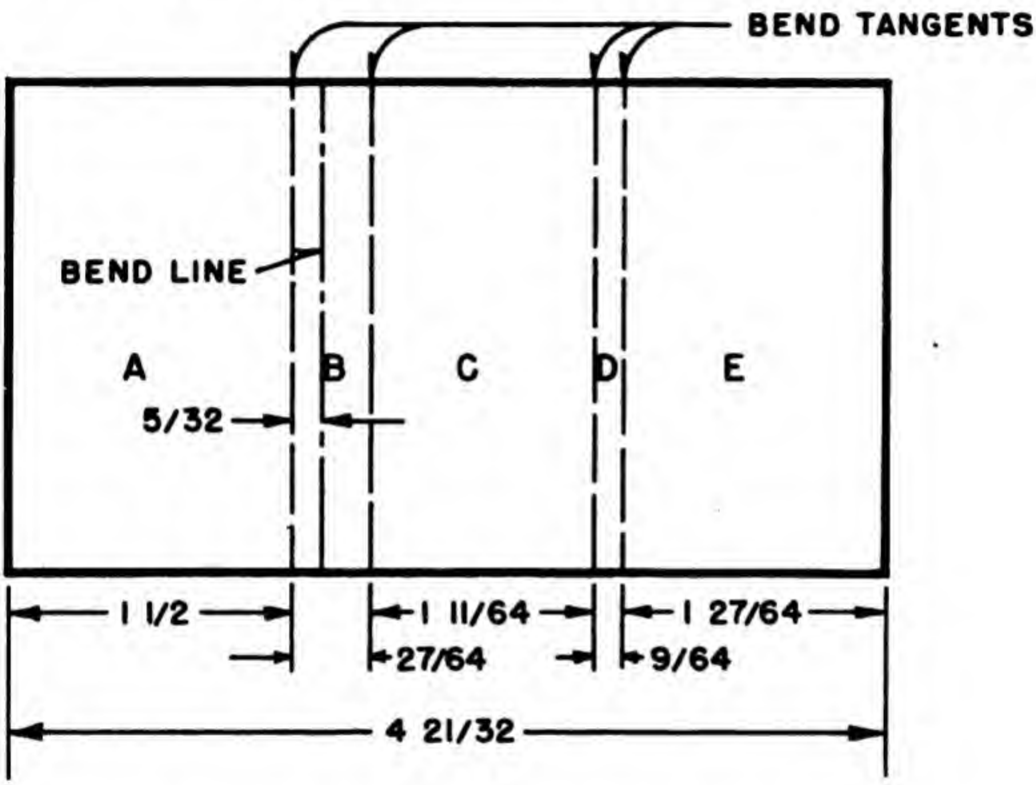


Figure 36.—Layout for open- and closed-angle job.

In figure 36, the bend tangent lines indicate the portions which are bent. Before forming each bend, it must be decided which end of the material can be most conveniently inserted in the brake. Then the bend line is measured and marked with a soft pencil from the bend tangent line closest to the end which is to be placed under the brake. This measurement should be equal to the radius. The metal is inserted in the brake so that the nose of the brake will fall directly over the bend line, as shown in figures 29 and 36.

After the flat pattern layout has been made, the metal may be bent by either a cornice brake, bar folder, or form blocks. In each case, the radius of the part over which the metal is to be bent must be exactly the amount used as the bend radius in the flat pattern calculations. Exact results can be obtained in the cornice brake by using radius bars which may be attached to the lower side of the clamping jaw of the brake. If no radius bars are available, pieces of sheet aluminum should be formed and clamped over the jaw of the brake until the nose has the desired radius.

Regardless of the method of bending, the metal must be held so that the bend begins at the bend tangent line. In the cornice brake, this can be done as shown in figure 32. Locate the bend line the length of the radius from the bend tangent line which is to go under the brake, as demonstrated in figure 36. By eye, or by means of a combination square, locate the bend line directly beneath the nose of the brake. The bend line is put in an identical position at the edge of the blade of the bar folder.

If the bend is made with steel, micarta, or wooden form blocks, the bend line is made to line up with the edge of the form blocks, as illustrated in figure 37.

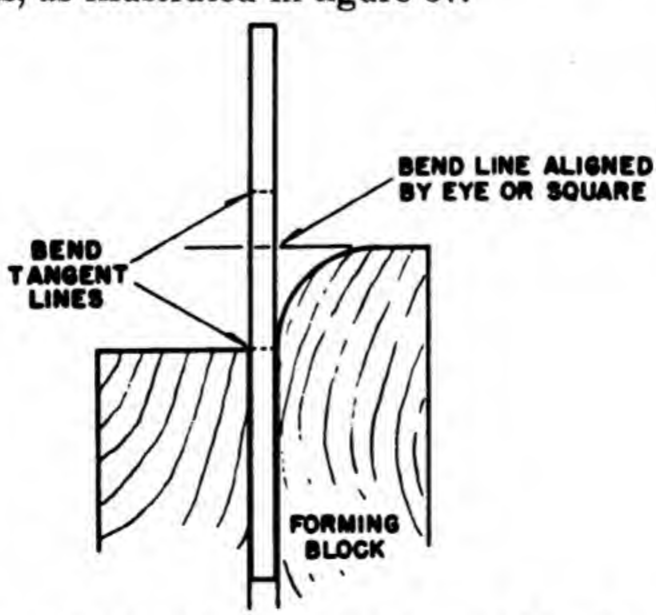


Figure 37.—Form blocks used for alinement of bend line.

Bends must be at an angle as near 89° to the grain of the metal as circumstances will permit.

A°	K	A°	K	A°	K	A°	K
1	0.00873	46	0.42447	91	1.0176	136	2.4751
2	.01745	47	.43481	92	1.0355	137	2.5386
3	.02618	48	.44523	93	1.0538	138	2.6051
4	.03493	49	.45573	94	1.0724	139	2.6746
5	.04366	50	.46631	95	1.0913	140	2.7475
6	.05341	51	.47697	96	1.1106	141	2.8239
7	.06116	52	.48773	97	1.1303	142	2.9042
8	.06993	53	.49853	98	1.1504	143	2.9887
9	.07870	54	.50952	99	1.1708	144	3.0777
10	.08749	55	.52057	100	1.1917	145	3.1716
11	.09629	56	.53171	101	1.2131	146	3.2708
12	.10510	57	.54295	102	1.2349	147	3.3759
13	.11393	58	.55431	103	1.2572	148	3.4874
14	.12278	59	.56577	104	1.2799	149	3.6059
15	.13165	60	.57735	105	1.3032	150	3.7320
16	.14054	61	.58904	106	1.3270	151	3.8667
17	.14945	62	.60086	107	1.3514	152	4.0108
18	.15838	63	.61208	108	1.3764	153	4.1653
19	.16734	64	.62487	109	1.4091	154	4.3315
20	.17633	65	.63707	110	1.4281	155	4.5107
21	.18534	66	.64941	111	1.4550	156	4.7046
22	.19438	67	.66188	112	1.4826	157	4.9151
23	.20345	68	.67451	113	1.5108	158	5.1455
24	.21256	69	.68728	114	1.5399	159	5.3995
25	.22169	70	.70021	115	1.5697	160	5.6713
26	.23078	71	.71329	116	1.6003	161	5.9758
27	.24008	72	.72654	117	1.6318	162	6.3137
28	.25862	73	.73996	118	1.6643	163	6.6911
29	.25863	74	.75355	119	1.6977	164	7.1154
30	.26795	75	.76733	120	1.7320	165	7.5957
31	.27732	76	.78128	121	1.7675	166	8.1443
32	.28674	77	.79543	122	1.8040	167	8.7769
33	.29621	78	.80978	123	1.8418	168	9.5144
34	.30573	79	.82434	124	1.8807	169	10.385
35	.31530	80	.83910	125	1.9210	170	11.430
36	.32492	81	.85408	126	1.9626	171	12.706
37	.33459	82	.86929	127	2.0057	172	14.301
38	.34433	83	.88472	128	2.0503	173	16.350
39	.35412	84	.90040	129	2.0965	174	19.081
40	.36397	85	.91633	130	2.1445	175	22.904
41	.37388	86	.93251	131	2.1943	176	26.636
42	.38386	87	.94896	132	2.2460	177	38.188
43	.39391	88	.96569	133	2.2998	178	57.290
44	.40403	89	.98270	134	2.3558	179	114.590
45	.41421	90	1.00000	135	2.4142	180	Infinite

Chart 2.—K chart.

FORMING OF ALUMINUM

Forming is an operation which tends to change the shape or contour of a flat sheet. In the manufacture of aircraft, the majority of the aluminum sheet parts are formed by machines in order to expedite production and hold cost at a minimum. On the other hand, field repairs are generally made by hand methods, since machines are seldom available.

Stretching and shrinking are operations used to produce curves, flanges, and various irregular shapes. Since the operations involve altering the shape of aluminum, the amount of shrinking and stretching depends almost entirely on the type of aluminum used. Fully annealed 2S, 3S, or 52S aluminum will withstand considerably more stretching and shrinkage than 17S and 24S, even if the latter are completely annealed. In other words, the softer the material the more hammering it can absorb, and conversely, the harder the material the less stretching and shrinkage is possible.

Stretching

In forming aluminum, the term stretching means to lengthen or increase a particular area. This does not necessarily harm the aluminum except that it thins the stretched section in about the same manner as a piece of rubber when it is stretched.

Several methods may be used to stretch metal. On ordinary flat pieces, the most common method is to force the metal to flow outward to the edges by hammering it over the surface of an anvil. By repeating this process and striking with a glancing motion in the direction the metal is intended to be stretched, the aluminum can be lengthened without creasing the surface.

An angle strip may be formed into a curve by stretching one side of its bent flanges, as shown in (A) of figure 38. For best results, this type of stretching is done in a V-block, pictured in (B), which has a slot for the angle and a V-opening over which the metal is hammered. Figure 38 (C) shows the important step in this procedure in which the angle strip is moved back and forth during hammering until the desired curve is obtained.

STRETCH IT

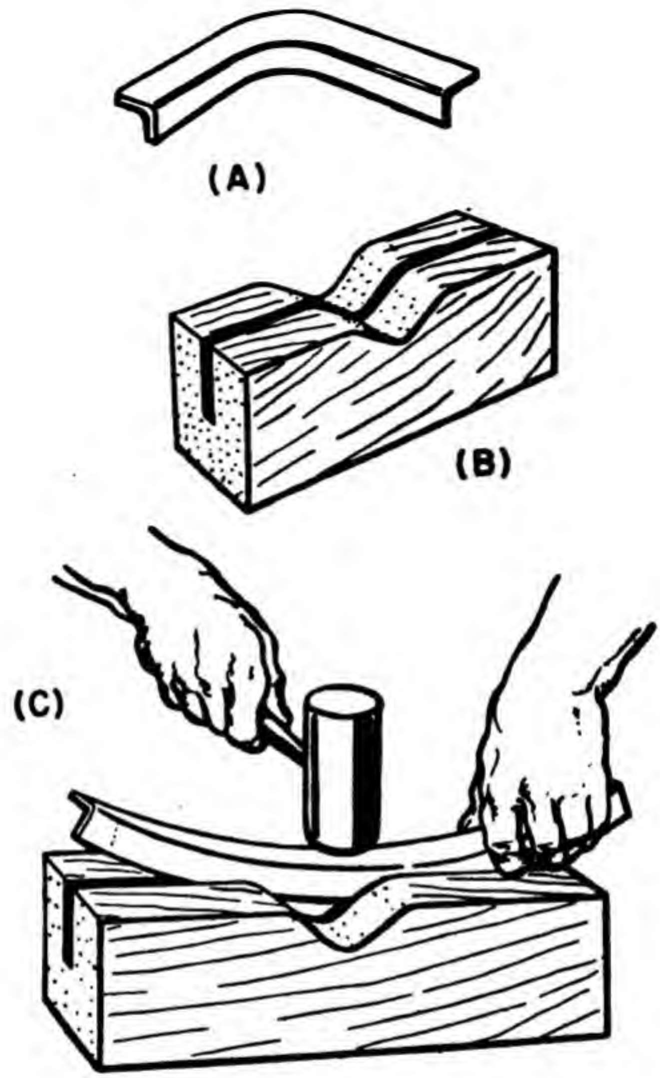


Figure 38.—Forming an angle strip by stretching.

Shrinking

Shrinking, as the name implies, refers to the reduction of an area of a piece of metal. This operation is used to develop curves as well as to straighten flat pieces. Thus, if a surface has been stretched too far, the metal must be shrunk to its original shape. Whereas stretching thins the metal, shrinking increases its thickness.

Shrinkage is accomplished by crimping the edge of the metal and then hammering out the crimp. To illustrate this procedure, a common operation of forming an angle strip will be used—bent opposite to that shown in figure 38.

To form such a curve, pictured as (A) in figure 39, the inside flange must be shrunk. The first step is to make a series of evenly spaced crimps on this flange, with either a pair of round-nose pliers or by hammering it over a V-block with a cross-peen mallet. The lower flange is held evenly on the V-block with the crimped surface on top, as may be seen in (C). The flat surface is then hammered lightly and uniformly with a mallet until the proper curvature is obtained. The crimps on the flange are next removed, but prior to hammering, it is necessary to clamp the strip to some surface by the use of blocks and clamps or a shrinking block in order to prevent the curve from straightening out. It is important that the flattening be started at the apex of the crimp and gradually worked toward the base.

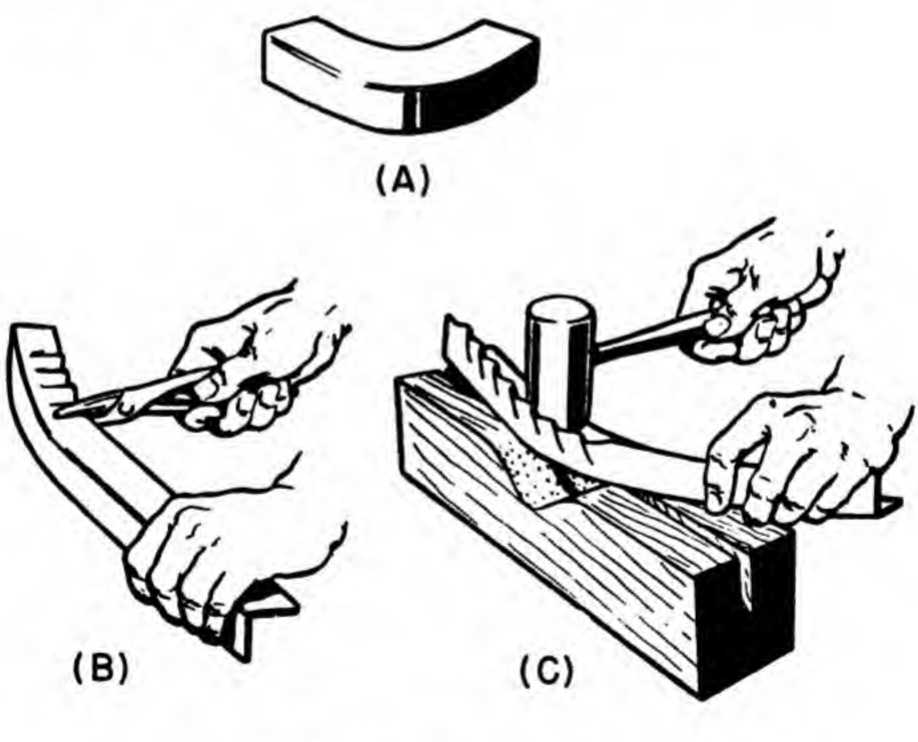
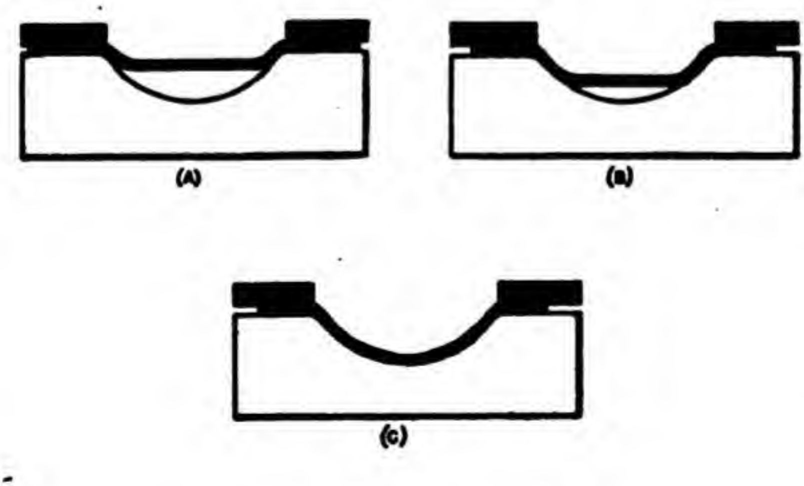


Figure 39.—Forming an angle strip by shrinkage.

Many sheet metal parts of an airplane require special forming. In regular production, such a part is stamped or pressed with power equipment. When replacement because of damage becomes necessary, the part must frequently be formed by hand. The metal is stretched by hammering it on a sandbag or a form block which has been hollowed out to the required shape of the part. The following description covers bumping, or raising of aluminum on a form block.

A rectangular piece of material of correct alloy and gage is cut to dimensions having at least 1-inch margin on all sides, and placed symmetrically on the form block.

The bumping operation begins by hammering the metal around the edge of the cutout in the hold-down plate with the use of soft round-nosed hammers of wood or pyrolin. The metal should be hammered so that it will always follow the form while it is being stretched down into the block so that it has a partial means of support, as shown in figure 40. For large areas where a very smooth surface is desired, small leather bags, called black jacks, filled with shot, are used to bump the metal. No tool marks are made, and the metal is rapidly shaped.



(A) (B) (C)

Figure 40.—Bumping procedure.

The metal should be carefully watched for indications of hardness due to work. When the metal tends to become springy, or the surface develops a grainy look—much like the skin of an orange—it should be annealed to relieve strain hardness.

When the part has been stretched into the shape of the form, a few hammer marks or evidences of roughness may exist which should be removed. When the bumping operation has been completed and the part is ready for installation, it should be heat treated, anodized, primed with zinc chromate primer, and painted. If the alloy is strain hardenable, the heat treatment is omitted.

Removing Dents

A task frequently performed by the Aviation Structural Mechanic is straightening aluminum surfaces that have been dented. Cowlings, wheel fairings, tail surfaces, and various other aircraft parts are often subjected to damage resulting in dents. With the proper technique, such damages can be repaired and the surface restored to its original shape and finish.

If the dent is small, place the concave side of the damaged surface on a metal stake or hardwood block and lightly hammer the dent with a flat-face wooden mallet, beginning the hammering around the edge and gradually working toward the center of the dent.

Where a large buckle exists, the best procedure is to place the surface on a hardwood backing block and press the metal into place rather than hammering it.

Flanging

In the fabrication of numerous aircraft parts, it is necessary to flange the edges. A straight right-angle flange is comparatively simple to form, but the task becomes slightly more difficult if a flange is required on a curved surface.

Let us assume that a nose rib must be made. The first step is to draw the required outline of the rib on two hardwood blocks and cut them out with a bandsaw. The edge

of one block must be slightly rounded to produce the required radius of the bend.

This done, draw the shape of the rib on a piece of the proper type of aluminum, allowing sufficient metal for the flanges. Draw a pencil line to represent the desired width of the flange around the curved edge, and cut along this line with a pair of snips. Place the metal between two blocks, making sure that the guide lines are even with the edges of the blocks, then lock the entire assembly with C-clamps and fasten it in a vise.

With a wooden mallet, begin hammering the extended edge downward, starting at one end and slowly working toward the other, repeating until the metal is flat against the side of the block. To form the flange around the curve, a back-up tool is used. This instrument is simply a wooden block with a wedge-shaped point.

The hammering on the curve should start at the inside edge of the block, using the cross peen of the mallet.

Sandbag Bumping

Sandbag bumping is a method of forming metal into a depression in a flexible bag with the aid of a mallet. There are many small parts of an aircraft which cannot be shaped in a brake, bar folder, or slip roll, but must be formed by shrinking or stretching. When this is necessary, the piece may be shaped either in a wood form block, steel die, or a depression in a sand bag. If several pieces of the same contour are to be made, form blocks or steel dies usually are employed. However, in many instances, it is more convenient and economical to shape the metal in a sandbag.

Sandbag forming can be used for a variety of jobs, from removing a simple dent in a cowling to fabricating a complicated streamlike fairing.

Bumping can be accomplished only on malleable metals. In aircraft construction and repairs, non-structural parts requiring bumping are usually made of a softer alloy, such as 2S, 3S, or 52S. When parts must be made of a heat-treatable alloy, they must be in a dead soft condition. The alloy must be kept malleable by frequent annealing.

The sandbag is made of some durable, closely woven material, such as heavy canvas or soft leather. In an emergency, any tough, heavy fabric would serve the purpose. Fine, dry sand is usually used as a filler, since it remains flexible and does not form hard lumps.

To accomplish all types of forming, a variety of hammers and mallets are used. Soft-faced mallets of either wood, fiber, or plastic give the best results on aluminum alloy since they have less tendency to mar or scratch the metal.

Joggling

A joggle is an offset bent on a flat sheet, angle, or channel to permit two overlapping pieces to form a flush surface, as may be seen in figure 41. On a flat sheet, such a bend may be easily made in a brake, but in angle strips or channel pieces a specially designed joggling block must be used. Joggling, as a rule, is avoided where the offset is 0.032 inch or less, providing the light skin over which it is placed does not dimple when riveted.

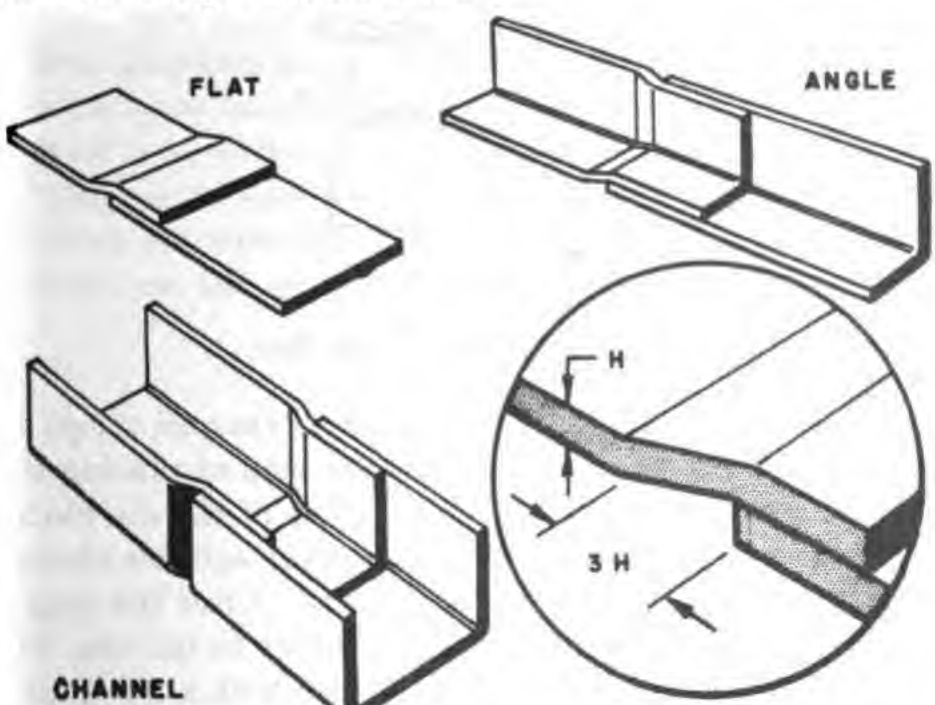


Figure 41.—Joggle.

To form an effective offset, the length of the joggle should be approximately three times the height.

To form a joggle in a flat sheet, first lay out the boundary lines where the bend is to occur. If the offset is to be made on the brake, clamp the piece between the jaw and bed, as shown in (A) of figure 42, and bend one leg approximately 20° to 30°. Then turn the piece over and clamp it in the brake, as demonstrated in (B). Raise the bending wing of the brake until the correct offset is produced, as shown in (C).

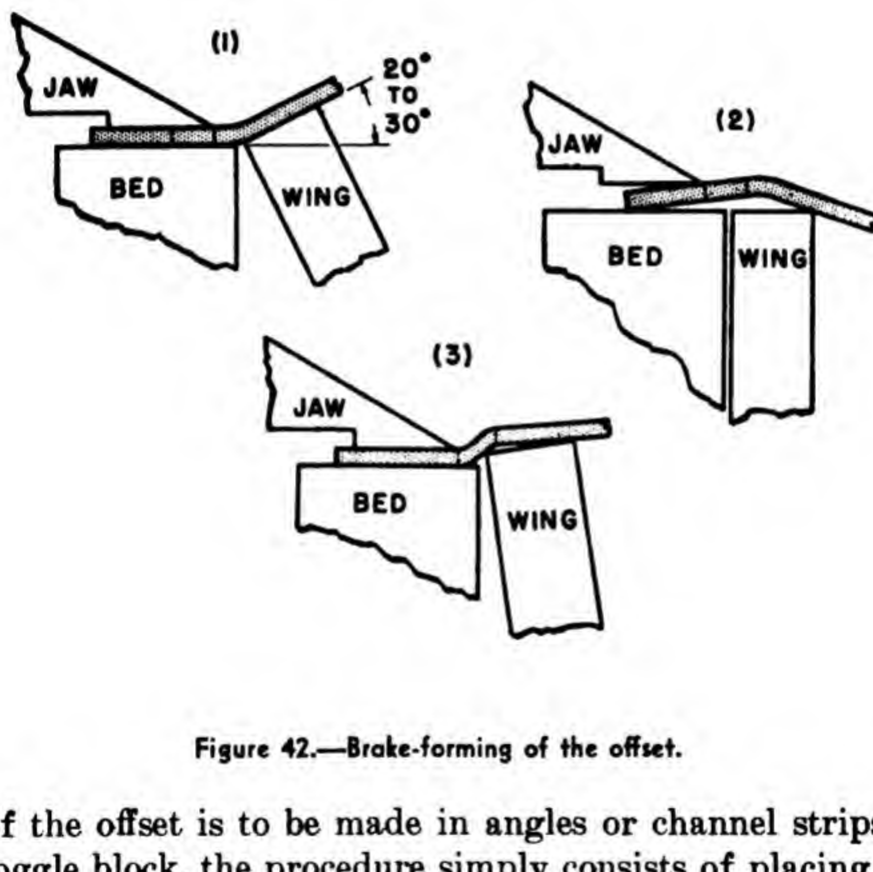


Figure 42.—Brake-forming of the offset.

If the offset is to be made in angles or channel strips in a joggle block, the procedure simply consists of placing the angle or channel between the two sections of the die blocks and squeezing them in a vise or some other suitable clamping device, as (A) of figure 43 discloses. After the joggle is formed, the joggle blocks are turned over in the vise and the bulge on the opposite angle is flattened with a wood mallet, as may be seen in (B).

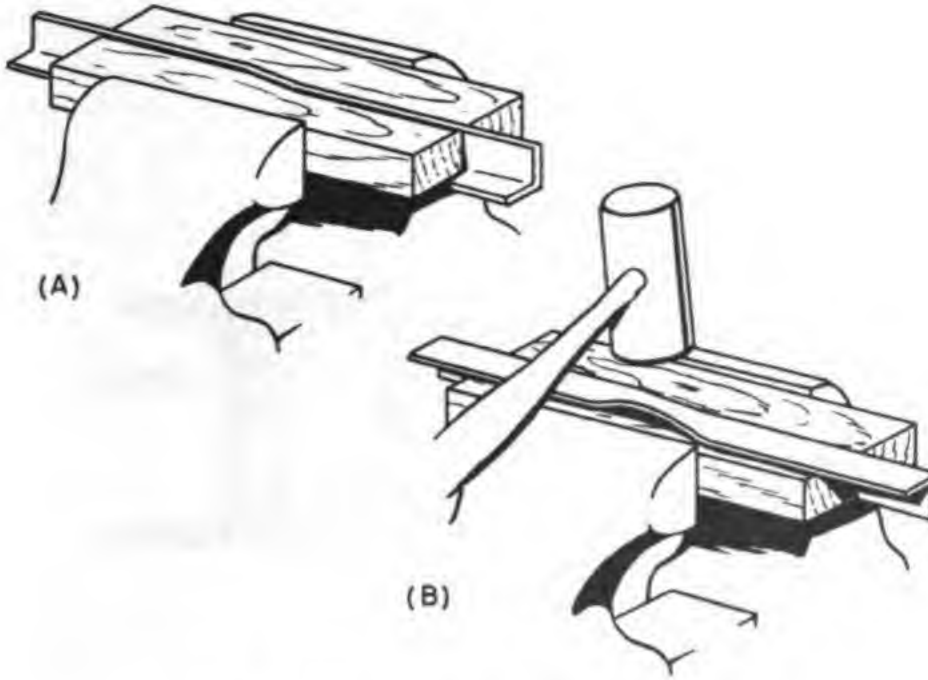


Figure 43.—Joggle-block forming of the offset.

QUIZ

1. Name three types of seams.
2. What allowance should be made for a wire edge?
3. What is the amount of material used in making a bend known as?
4. What is the outside or over-all dimension of a part called?
5. What are the lines that indicate where the bend begins and ends?
6. Which will stand the most forming, 2S or 17S aluminum alloy?
7. What are the proportions of an effective offset?

CHAPTER 5

RIVETS AND RIVETING

The thousands of rivets that go into the construction of the modern airplane—more than 150,000 in a medium bomber and nearly half a million in a large bomber—indicates the importance of rivets and riveting. The Aviation Structural Mechanic, therefore, must be a skilled riveter and thoroughly familiar with the various types of rivets. He must be able to identify head shapes, alloy composition, and be able to select the proper kind and size of rivet for a given job.

Riveting is the most common method of joining aluminum alloy, particularly the structural alloys which depend upon previous heat treatment to maintain their high mechanical strength. The rivets used of aluminum-alloy structures are made from several wrought-aluminum alloys.

TYPES OF AIRCRAFT RIVETS

For various structural situations, engineers base their selection of rivets on the kind of alloy and its heat treatment, the size or diameter of the shank, and the type of rivet head. The spacing of the rivets must also be carefully con-

sidered. Too many rivets may weaken the structure because of the material that must be drilled away, while too few rivets may not develop sufficient strength.

Rivets are designed and intended to be used in shear stress only. They are not well suited for transmitting loads in tension because a slight eccentricity of load exerts a prying action on the head which may result in early failure of the rivet.

Rivets used in aircraft construction rarely exceed $3/16$ inch in diameter. The majority used have a diameter of $1/8$ inch. The AN (Army-Navy) standard aluminum and aluminum-alloy rivets are made in four basic head shapes which are identified by the code numbers shown in figure 44.

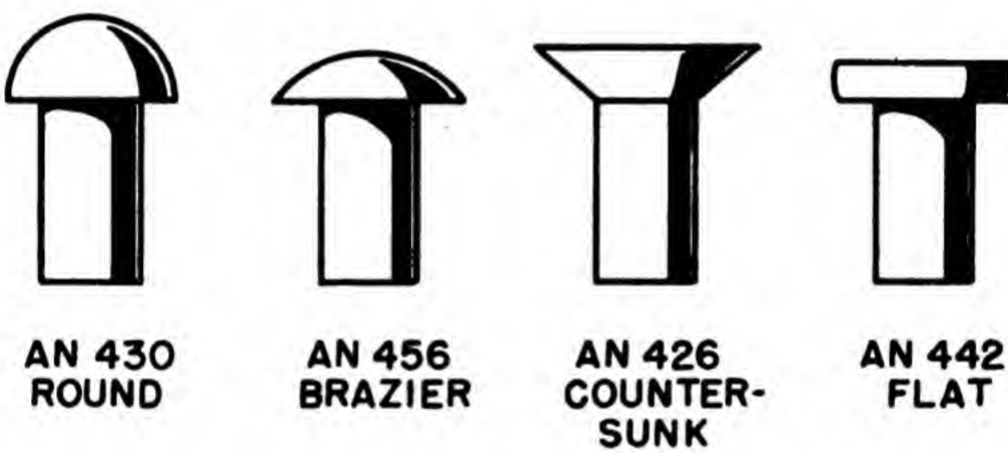


Figure 44.—Four basic head shapes of rivets.

The round-head type of rivet is used on relatively thick sheets where strength is required. The size of the head is such that it covers a sufficient area around the hole and at the same time offers considerable resistance tension.

The brazier-head type of rivet is used extensively for the riveting of thin sheet (skin) exposed to the slip stream as it offers little resistance to the air. The large diameter of the head makes it particularly adaptable for use in thin sections.

The countersunk-head type of rivet is used for riveting thick sheets over which other plates must fit. Countersunk-

head rivets are also used extensively for riveting thin sheets exposed to the slip stream.

The flat-head type of rivet is sometimes used for internal riveting where increased clearance is required.

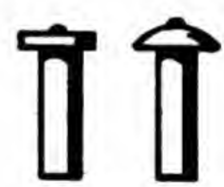
COMPOSITION OF AIRCRAFT RIVETS

Aircrafts rivets are made principally from four kinds of aluminum or aluminum alloys. To simplify identification, aluminum manufacturers have marked the heads of rivets as illustrated in figure 45, and any head shape may be any of the four alloy designations. A brazier head rivet, for example, could be a type A, D, AD, or DD. The alloy composition of rivets is designated by the following code of letters.

2S and 3S	none or A
17S	D
24S	DD
A17S	AD

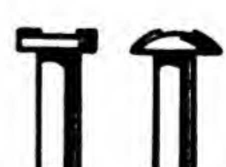
Notice that 2S and 3S rivets, type A, have a plain head without markings. To distinguish between the two, they are sometimes stamped "2," "3," or "5" on the end of the shank, denoting 2S, 3S, or 52S.

TYPE A, 2S, 3S, OR 52S ALLOY
(DO NOT HEAT TREAT
BEFORE USING)



TYPE D, RAISED DOT 17S-T
(HEAT TREAT BEFORE USING)

TYPE AD, DIMPLE A17S-T
(DO NOT HEAT TREAT
BEFORE USING)



TYPE DD, RAISED BARS 24S-T
(HEAT TREAT BEFORE USING)

Figure 45.—Alloy identification markings for rivets.

The 17S–T rivet, type D, has a bump or raised dot on the center of the head for identification.

A dimple in the center of its head identifies the A17S–T rivet, type AD.

The 24S–T rivet, type DD, is identified by two raised bars, or dashes, on opposite sides of the head.

The selection of rivets is based on their strength and working or driving properties. For example, 2S and 3S are relatively soft. They are always driven cold as received, and storing them, even for an indefinite period, does not affect their strength or driving characteristics. They are used only for nonstructural parts that are lightly stressed, such as for the riveting of pyralin or plexiglas windshield frames.

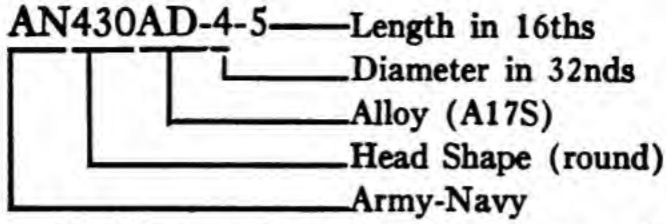
Two of the most commonly used rivets are 17S and 17S–T. (The "T" in the identification symbol of the latter indicates that it has been fully heat-treated.) Rivets of the 17S alloy must always be heat-treated to obtain maximum strength, while 17S–T rivets must also be heat-treated to anneal or soften them for driving.

Where strength higher than that of 17S–T is required, 24S–T rivets are sometimes used. Rivets of 24S–T are slightly more difficult to drive than those of 17S–T; consequently they are usually used to join harder and heavier gage alloy sheet.

A–N RIVET CODE

A system of letters and numerals has been adopted by the Army and Navy to standardize the specification of aircraft rivets. As an example, let us suppose that you received instructions to use an AN430AD–4–5 rivet, and determine exactly what the code would imply.

The letters AN indicate Army-Navy specifications. The three digits—430—state the head shape of the rivet. The two letters, AD, designate the alloy from which the rivet is made. A set of two dash numbers—in this case, –4–5—tell the diameter and the length of the rivet. The first dash number indicates the diameter in thirty-seconds of an inch and the second, the length in sixteenths of an inch. This example is further outlined in figure 46.



Note: Observe the position of the dashes in the example and be consistent in their use.

Figure 46.—A–N rivet coding example.

RIVET AND DRILL SIZES

Although riveting is a more recent development than welding in aircraft construction, the technique of riveting is more easily and quickly learned than that of welding. While the safety and perfection of a metal joint, whether riveted or welded, depend largely on the skill of the mechanic, there is much less chance of hidden flaws due to poor workmanship in riveted construction.

Riveted joints must be strong enough to transfer safely the forces acting on the parts joined. The size, spacing, and edge distance of rivets are among the important determining factors.

Rivets are obtainable in various diameters and lengths. The most common rivet diameters are shown in chart 3, which also gives the size of drills to be used for the various diameters of rivets. A drill from 0.002 to 0.004 inch larger than the rivet should be used for sheet and plate riveting.

There are three factors you must remember in selecting the correct rivet for the job. These factors are: the composition of the rivet, the rivet diameter, and the rivet length.

RIVET COMPOSITION

The selection of the correct aluminum-alloy rivet is important, since the full shear strength of the riveted joint depends upon the proper combination of material and rivet.

Rivet shank diameter	Drill No.	Drill decimal
1/16	52	0.0670
3/32	41	.0980
1/8	30	.1285
5/32	21	.1590
3/16	11	.1910
1/4	F	.2570

Chart 3.—Drill sizes for rivets.

If a hard rivet, such as 17S, were to be driven into a soft plate, such as 2S–O or 3S–O, the resulting effect would be a distortion of the sheet. Moreover, the value of the high shear strength of the 17S rivet would be completely lost in this soft metal.

Although it is considered a poor practice to drive a hard rivet into soft metal, at times it may be advisable to use a soft rivet for hard material, especially if the joint is not subjected to any undue high stress. Generally speaking, however, it is recommended that the material of the rivet possess the same properties as the aluminum sheet. Chart 4 is a good guide for this purpose.

Rivet type	Use
A	Parts fabricated from 2S and 3S alloys.
AD	Parts fabricated from 17S and 24S alloys.
D	Parts fabricated from 17S and 24S alloys.
DD	Parts fabricated from 24S alloy and as a substitute for types AD and D rivets.

Chart 4.—Selection of rivets.

To secure the full strength of a riveted joint, a rivet of the correct length and diameter must be used. For example, if a large-diameter rivet were inserted in a thin sheet, the pressure required to drive the rivet would result in bulging the thin metal around the rivet head. The accepted rule is to use a rivet whose diameter does not exceed 2½ to 3 times the thickness of the thickest section through which the rivet is driven, as shown in figure 47.

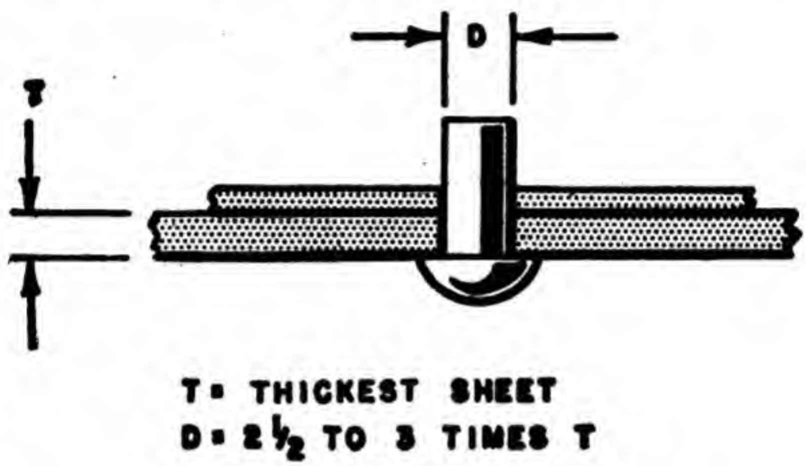


Figure 47.—Rivet diameter.

The rivet diameter should not be less than the thickness of the thickest plate through which it is driven. Rivets smaller than $\frac{3}{32}$ inch in diameter should not be used for any structural parts which carry stress, and very few rivets are used which are over $\frac{5}{16}$ inch in diameter.

RIVET LENGTH

It is also decidedly important that the rivet be of the correct length, since a rivet that is too long has a tendency to bend when headed. On the other hand, a rivet that is too short will prove too difficult to head and almost impossible to shape properly. THE CORRECT LENGTH OF THE RIVET SHOULD EQUAL THE SUM OF THE THICKNESS OF THE METAL PLUS 1½ TIMES THE DIAMETER OF THE RIVET SHANK, as shown in figure 48.

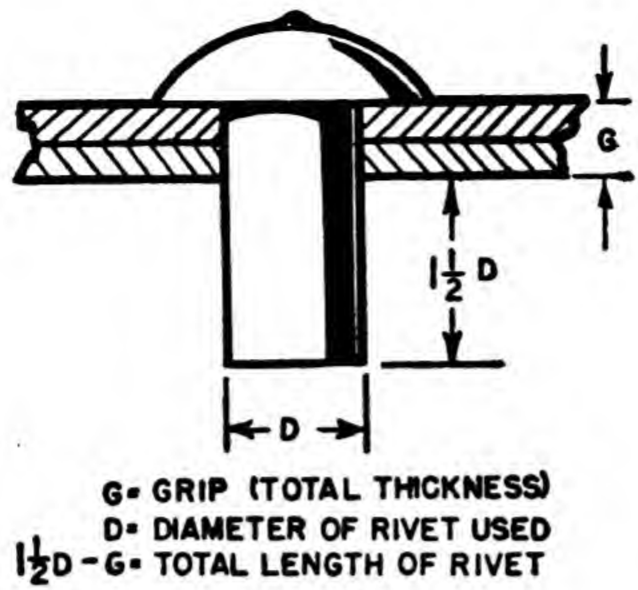


Figure 48.—Rivet length.

The maximum length of the rivet shank before driving should not be more than 1.75D.

BUCKTAIL SIZE

What constitutes a properly headed rivet is another factor with which a riveter must be fully familiar if the riveting job is to pass successful inspection. In other words, a rivet, to be effective, must be squashed within certain limits, and this can only be done if all the conditions previously mentioned have been met, particularly in regard to the correct-length rivet. In general, the height of the "bucktail" should equal one-half the diameter of the rivet and the minimum width 1½ times the rivet diameter. For example, a properly headed ⅛-inch rivet should extend a distance of $\frac{1}{16}$ inch above the surface of the metal with a head approximately $\frac{3}{16}$ inch across the flat. Figure 49 shows a before-and-after view of the heading process.

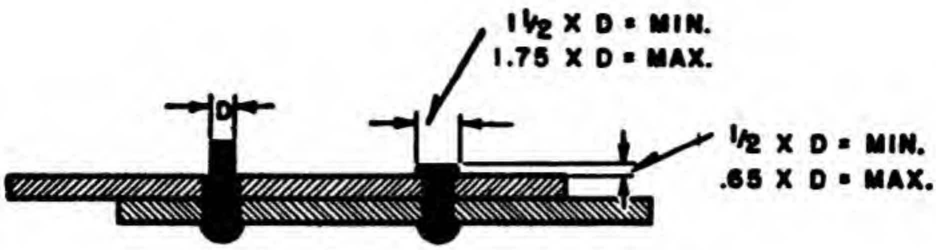


Figure 49.—A properly headed rivet.

RIVET SPACING AND EDGE DISTANCE

The spacing of a riveted joint usually depends upon the proportions of the members joined. The minimum spacing is governed by driving conditions, that is, sufficient space between rivets must be allowed to permit them to be driven without interference.

A general rule covering the spacing of rivets recommends a minimum distance of 3 times the rivet diameter, and a maximum of 24 times the thickness of the thinnest sheet through which the rivet passes.

In practice, the center to center distance is usually from 4D to 8D, depending upon the requirements of the job at hand.

For maximum bearing strength, the EDGE DISTANCE measured from the center of the hole in the direction of stressing to the edge of the sheet should be at least twice the diameter of the rivet hole. Aside from considerations of strength, rivets that are too close to the edge tend to bulge the sheet and cause an unsightly finished joint. If, however, rivets are set too far back from the edge, the sheet tends to curl. This condition does not contribute to a sound or waterproof seam. This rule is illustrated in figure 50.

For general repair work, the following conditions may prove helpful.

The rivet size should be the same as that of the original rivets as far as possible, or larger.

The spacing should be kept the same as the spacing of the part being repaired unless closer spacing may be necessary.

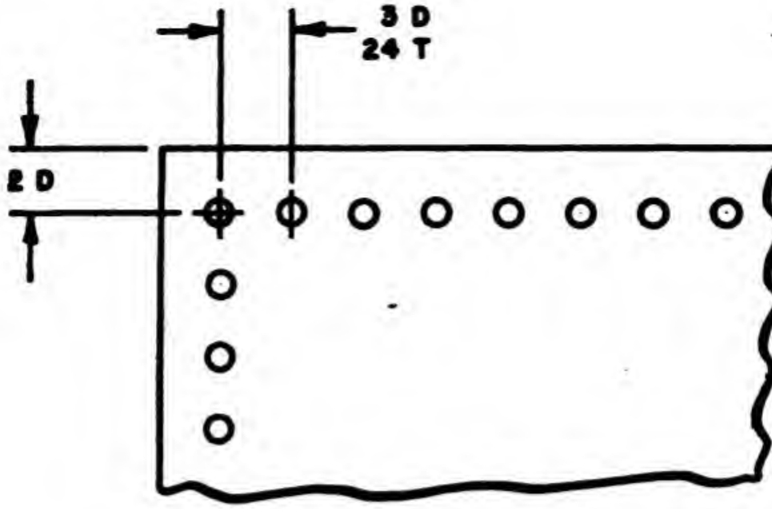


Figure 50.—Rivet spacing.

Enough rivets must be installed to insure the strength of the parts to be joined.

SELECTION AND USE OF ALUMINUM ALLOY RIVETS

The following are rules for the selection and use of rivets made of the three common aluminum alloys, A17S–T, 17S–T, and 24S–T.

A17S–T rivets may be used for general repair purposes, including floats and hulls, provided the following restrictions are observed.

They shall be used SIZE FOR SIZE where they are specified in the manufacturer's drawings.

They may be used INSTEAD of specified 17S–T rivets if the next larger size rivet is used and if edge distances are maintained.

They can be used when it is necessary to drill existing rivet holes oversize because of elongation of the hole.

A17–S–T rivets are inferior to 17S–T in strength and corrosion resistance.

The Bureau of Aeronautics has authorized the use of all A17S–T rivets except on floats and hulls made of non-clad 24S–T material. On such material the use of 17S–T and 24S–T rivets is still required.

17S–T RIVETS may be used to replace 24S–T rivets, provided the next larger size is used and provided edge distances are adequate.

You must adhere strictly to heat-treatment procedures and to rules for usage after heat-treatment.

24S–T RIVETS are used only when required or by written engineering instructions.

HAND RIVETING

Although most aircraft riveting is performed by various types of riveting machines, small sections are occasionally riveted by hand. To carry out such an operation, two tools are needed—a hammer and a bucking block. A medium weight ball-peen hammer or a riveting hammer may be used. Never use too heavy a hammer, because such practice will stretch the metal excessively, while one that is too light may prove ineffective in heading the rivet, causing the shank to bend.

The bucking-block should have a cup-like depression in the end to receive the rivet head. To prevent distorting the shape of the head, the cup must be slightly shallower and wider than the head of the rivet. Figure 51 (A) shows correct and incorrect shapes for this cup-like depression. A rivet header such as is used on pneumatic riveters makes a very good bucking bar for hand riveting when supported in a steel block. Any piece of steel or cast iron will do. Simply drill a hole in the metal and insert the shank of the header, as shown in figure 51 (B)

In starting a riveting job, the parts to be fastened together are held by clamps, sheet-metal screws, speed fasteners, machine screws, or by clamping in a smooth-jawed vise. If the parts have not been predrilled, rivet holes must be drilled or reamed to size if they have pilot holes. If drilling is necessary, the parts should be removed later from the temporary clamping and the chips and burrs cleaned from around the holes. Rivet holes tend to get out of alignment during the riveting operation because of slippage, swelling, or stretching of the metal, and for this reason, work should be assembled firmly before driving. The temporary fasteners

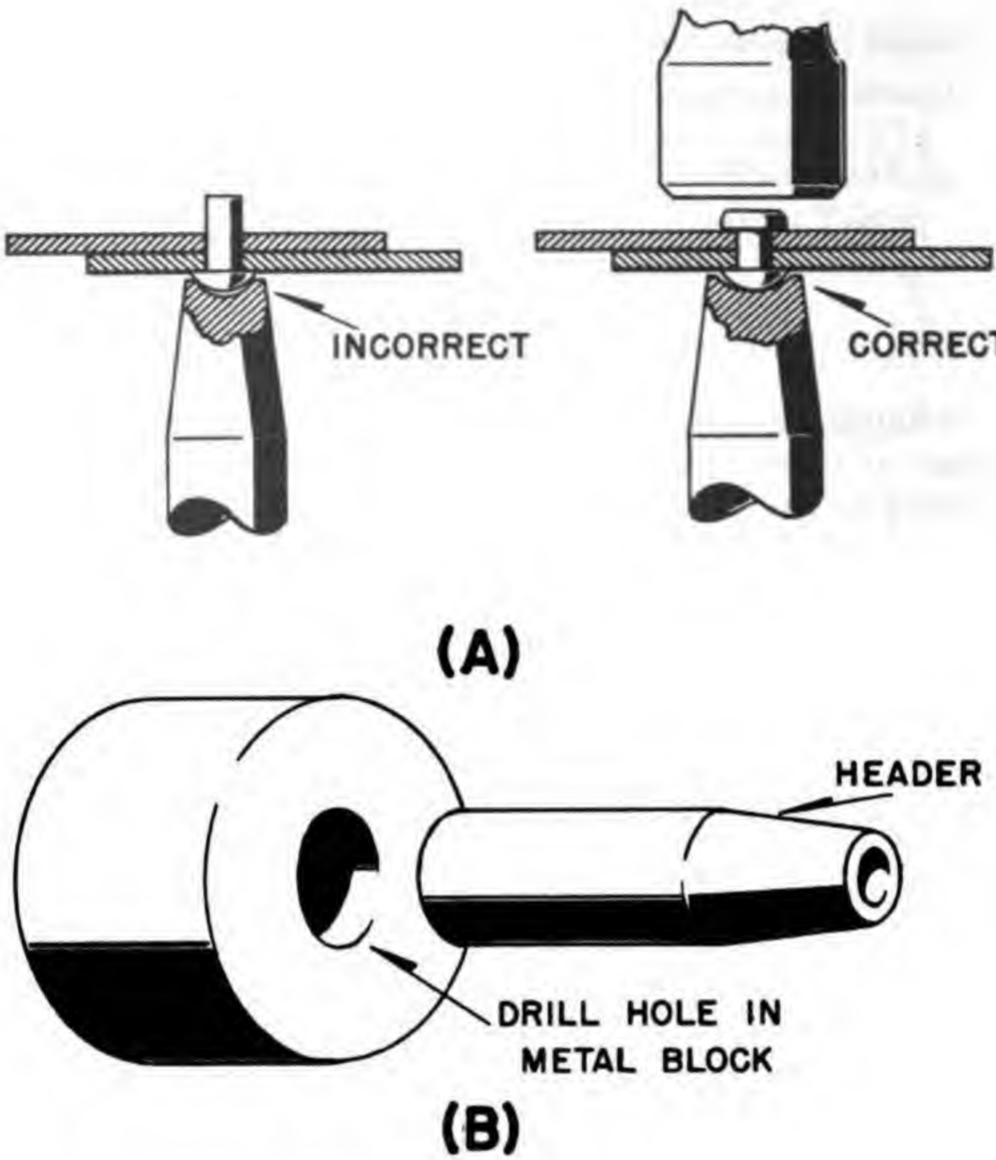


Figure 51.—Bucking blocks.

should not mar the metal parts, but should be sufficiently tight to prevent the rivets from squeezing out or flashing between the parts of the joint.

Determine the diameter and length of the rivet to be used. This done, place the section of metal to be riveted over the bucking block with the rivet head resting in the cup, as shown in figure 52 (A). If the riveting is to be done on a

structural piece, a separate rivet set and bucking bar must be used, as illustrated in figure 52 (B).

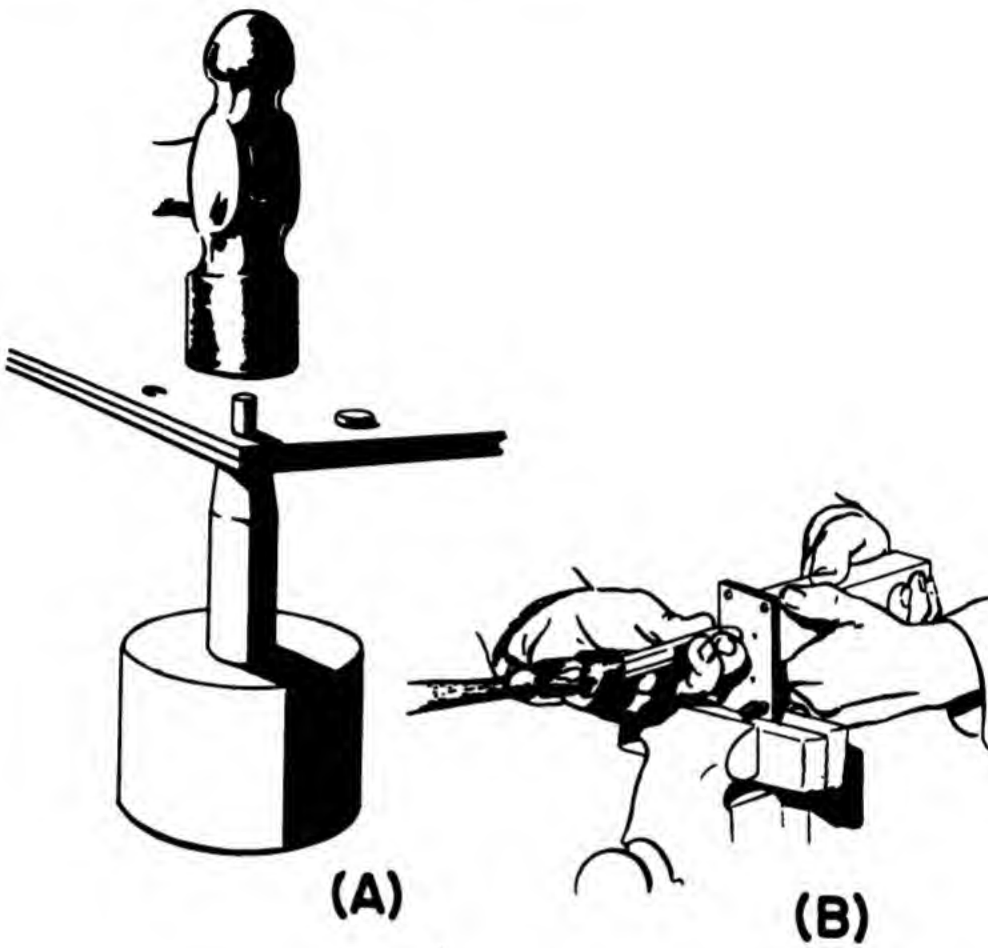


Figure 52.—Riveting.

Strike the end of the rivet with the face of the hammer, making certain that each blow hits the rivet shank squarely. After striking the rivet a few times, check the bucked end.

DRILLING OUT A RIVET

Occasionally you will be confronted with the job of removing rivets from an aluminum surface. Although the operation is relatively simple, certain precautions must be taken to avoid ruining the section. The usual procedure for drilling out rivets is as follows:

Lightly center punch the heads of the rivets as in (A) of figure 53.

Select a drill that is slightly smaller in size than the shank of the rivet.

Drill through the head of the rivet only, as shown in (B). If the drill is run through the entire rivet, there is a possibility of cutting into the sheet.

With a cold chisel, knock off the drilled heads, as depicted in (C). To keep the chisel from marring the surface of the metal, its cutting edge should be slightly rounded.

Finally, drive out the remaining part of the rivet with a pin punch, as in (C).

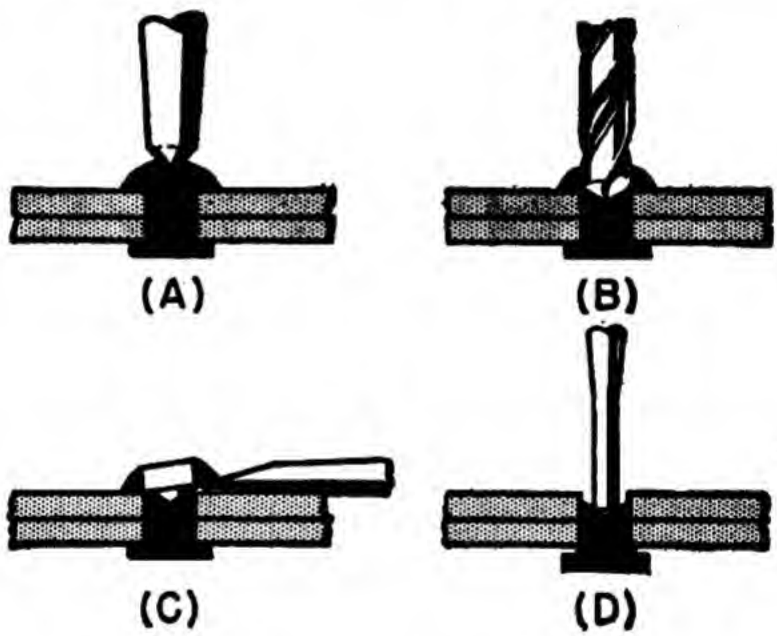


Figure 53.—Drilling out a rivet.

PNEUMATIC RIVETING

Pneumatic riveters come in several different types, sizes, and makes, and are classified according to their operation. The most common types are the slow hitting, fast hitting, one shot, and compression or squeeze types.

Slow hitting rivet hammers have a speed up to approximately 2,500 BPM (blows per minute). The fast hitting hammers range from 2,500 to 5,000 BPM. These slow and fast hitting hammers are available in different shapes and sizes, several of which are illustrated in figure 54.

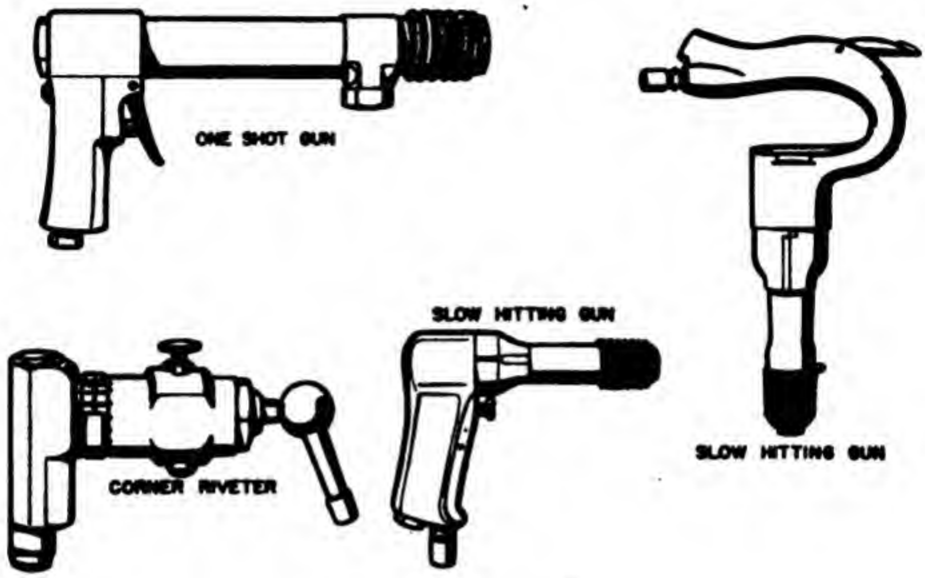


Figure 54.—Riveting hammers.

One shot riveting hammers are generally larger than either slow or fast hitting hammers. As the name implies, the valve mechanism is so designed that each time the trigger is pulled the rivet will be headed with one blow.

Pneumatic squeeze riveters range from small portable to the large stationary types, and have interchangeable rivet sets so that all types of rivets may be driven. When the trigger is pulled, the flat set or the bucking bar moves forward on one side and bucks the head with a direct squeezing action against a rivet set of the proper head type on the other side of the jaw.

These sets are adjustable so that various size rivets can be driven to the proper heights. A work-saving feature of the squeeze riveter is that after it is set, all of the rivets will be driven in a uniform manner.

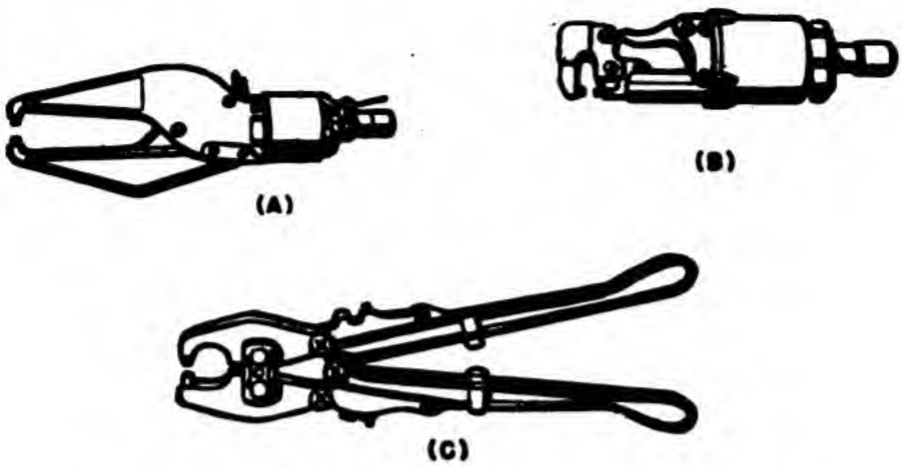


Figure 55.—Portable squeeze riveters.

The size and type of gun used for a particular job depends upon the size and type of alloy rivets required and the accessibility of the rivets to be driven.

For driving medium-sized, heat-treated rivets which are in accessible places, the slow hitting gun is the most widely used. For small, soft alloy rivets, the fast hitting gun is preferable. There will be places such as corners where medium-sized rivets are used that a conventional type gun cannot be employed. For this type of work, a corner gun, or one having an offset rivet set, is used.

A squeeze riveter should be used on the trailing edges, wing root sections, and along those edges where the yoke of this type of gun will fit. Figure 56 illustrates such a condition.

RIVET SETS

Rivet sets are removable steel dies used to transmit the blows from the gun to the rivet, and are held in the gun by retaining springs.

The ends or tips of the rivet sets are made to fit the manufactured head of the rivet. A set with a flat face, usually slightly crowned, is used for flush riveting. These dies should always be kept in good condition with a high polish, and free from nicks or scratches.

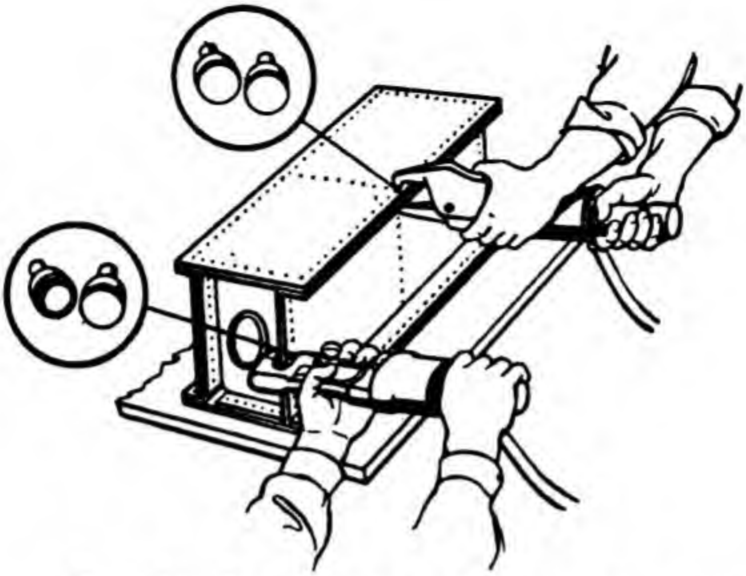


Figure 56.—Riveting with portable pneumatic squeezers.

Rivet sets are made in a great variety of sizes and shapes, as shown in figure 57. In many places where rivets cannot be reached with a straight set, or with a corner gun, you will use an offset, or angular set.

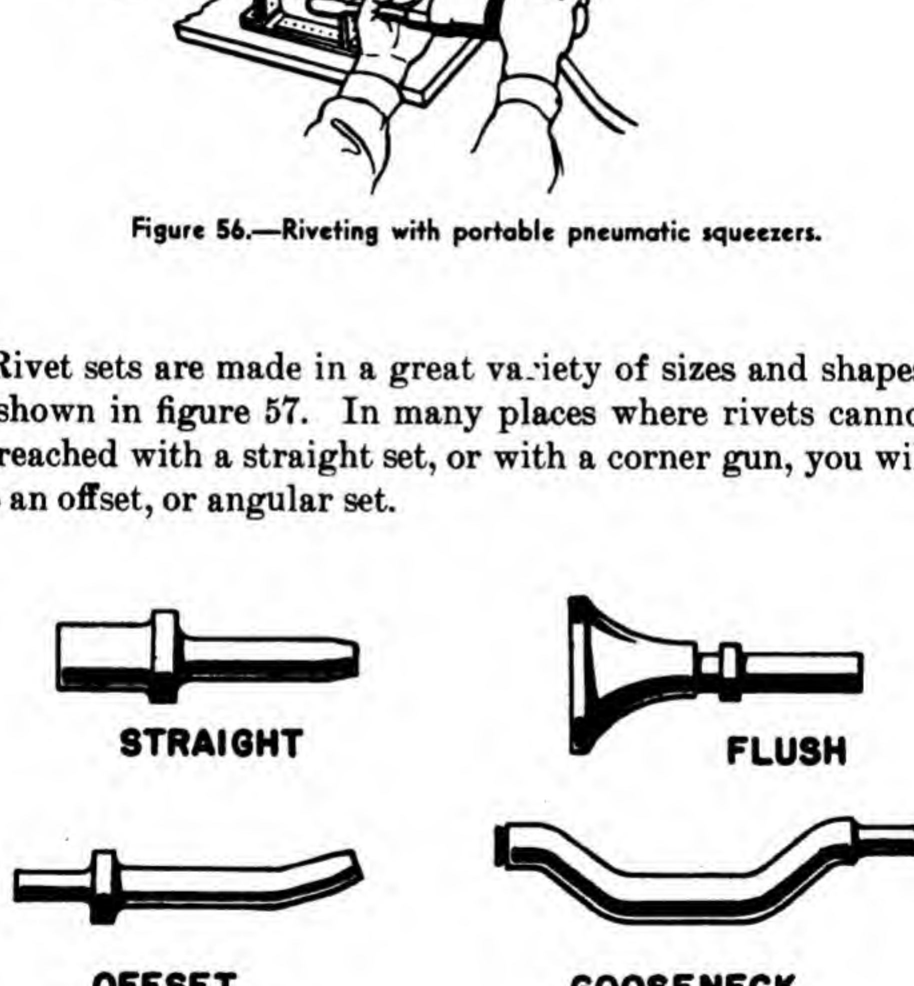


Figure 57.—Rivet sets.

Bucking bars are usually made of tool steel, and sufficiently heavy to buck the rivet solidly, yet light enough to facilitate ready handling. Actually, the size, shape, and weight of the bar will be determined by the size, kind, and location of

the rivets being bucked. Figure 58 illustrates several types of bucking bars, and in figure 59 are shown examples or bars used in various locations.

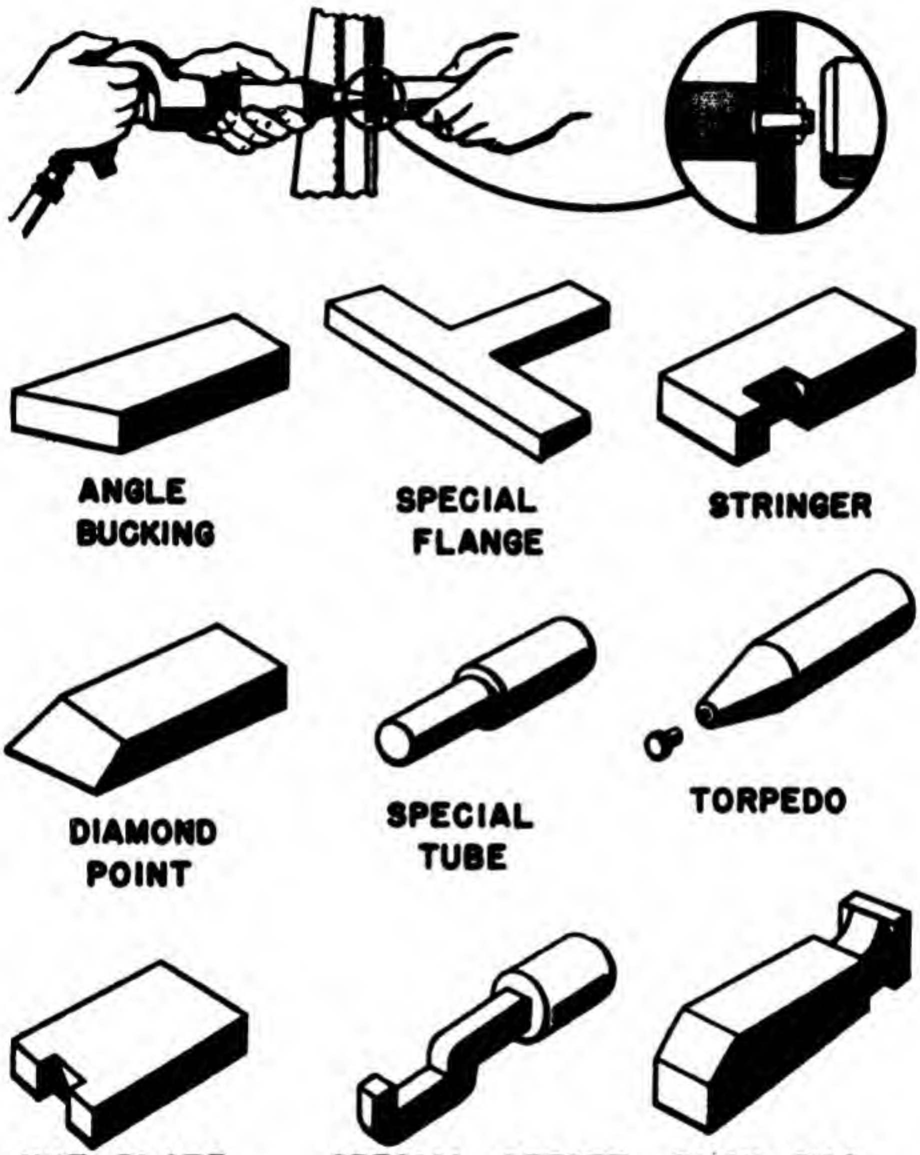


Figure 58.—Bucking bars.

PNEUMATIC-GUN RIVETING, OR GUNNING PROCEDURE

After making certain that the hole is the correct size, the

gun must be checked to ascertain whether or not it is adjusted correctly. It is very important in "gunning" a rivet to be able to judge the number of shots, or hammer blows, required for a correct upset head. The gun should be adjusted so that the rivet may be driven in the shortest possible time, but care must be taken not to drive the rivet so hard or in such a manner as to dimple the metal.

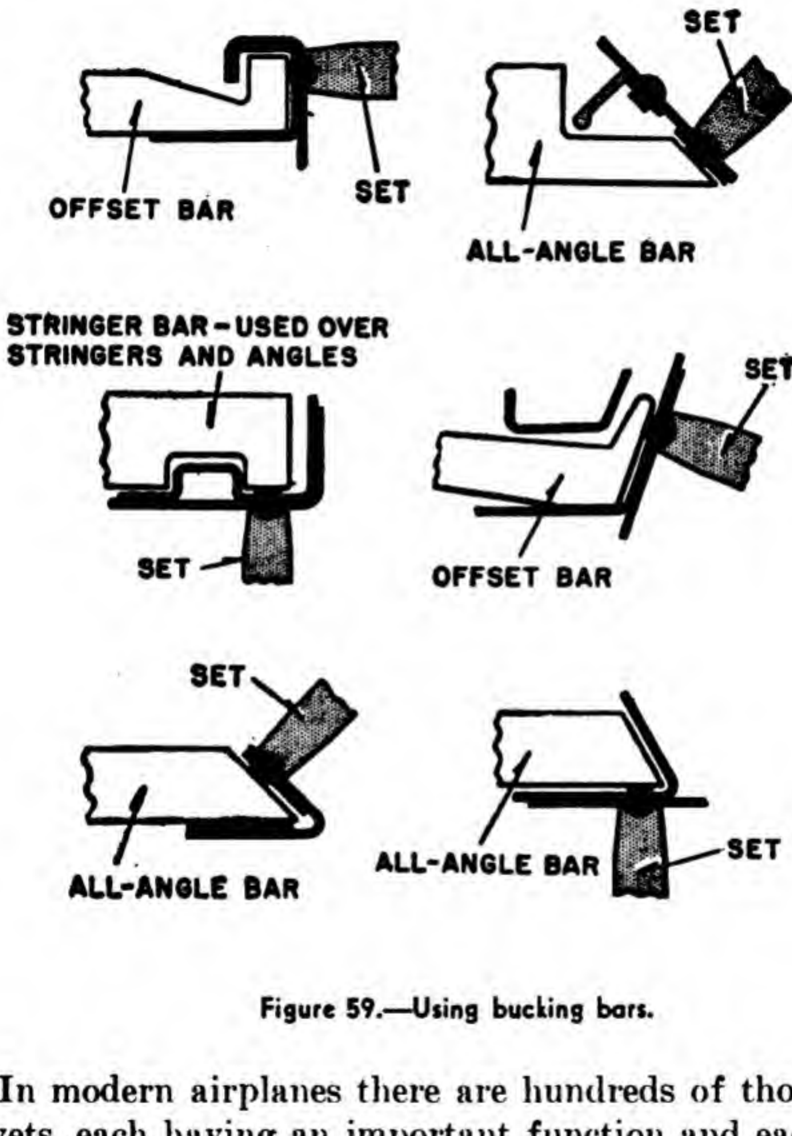


Figure 59.—Using bucking bars.

In modern airplanes there are hundreds of thousands of rivets, each having an important function and each able to stand only a definite amount of stress. If one rivet fails, the added burden on the next one and the next, may start a successive popping of rivets which will result in structural failure.

The following procedure will insure a good job of riveting:

1. Insert a rivet in a hole previously drilled through the metal to be riveted.

2. Place the rivet set and gun against the manufactured head.

3. The bucker on the opposite side of the metal places a bucking bar against the protruding shank of the rivet.

4. When the bucking bar is felt to touch the rivet, square the riveting set with the metal and compress the trigger of the gun, causing the hammer to strike the set, stopping the hammer after a few blows. The rivet set should never be removed until the rivet has been completely driven.

5. The bucker removes the bucking bar to check the reaction of the rivet to the first few blows. If the rivet has been properly swollen in the hole and is perpendicular to the material in all directions, the bucker replaces the bucking bar. This one-tap signal means "hit it again."

6. Continue "gunning" or driving the rivet. Skill in the number of blows for the correct upset head will have to be acquired through experience.

HEAT TREATMENT OF RIVETS

Strength is an all-important factor in the construction of aircraft. When it is understood that an airplane is held together principally by rivets, it may be readily seen why the Aviation Structural Mechanic must know his rivets. He must be familiar with rivet codes. He must be able to select the proper rivet for a given job, which means that he must know when and where to use heat-treated rivets and rivets that do not require heat-treating. He also must know how to heat-treat rivets and how to care for them so that the maximum benefit from their physical properties may be obtained.

STRENGTH OF RIVETS

Some idea of the importance of using the proper rivet may be had by comparison of the shearing and tensile strength of the 2S–H rivet and the 24S–T rivet.

As noted in chart 5, 2S–H rivets have a shearing strength of 13,000 pounds per square inch, and a tensile strength of 24,000 pounds per square inch, whereas 24S–T rivets have a shearing strength of 35,000 pounds and a tensile strength of 62,000 pounds. Thus, we see that 24S–T rivets are about three times stronger, which is extremely important as far as comparative strength is concerned. It is not difficult to imagine the result to a plane in which 2S–H rivets were used when 24S–T rivets were specified.

Type of rivet	Yield strength (p. s. i.)	Shear strength (p. s. i.)	Ultimate tensile strength (p. s. i.)
2S–H	21, 000	13, 000	24, 000
3S–H	25, 000	16, 000	29, 000
A17S–T	18, 500	25, 000	38, 000
17S–T	32, 000	30, 000	55, 000
24S–T	40, 000	35, 000	62, 000

Chart 5.—Comparison of rivet lengths.

As we learned earlier, there are two general groups of rivets. Types A and D rivets are those which can be used without heat-treating. Those which must be heat-treated before use are D and DD rivets. In addition to developing the maximum strength of the alloy, heat-treatment of 17S and 24S alloy rivets also make them soft so that they can be driven.

HEAT-TREATING EQUIPMENT

Equipment used for heat-treating rivets should provide means for accurately controlling and recording temperature. The success of the operation is directly dependent upon temperature control. If rivets are overheated, they begin to disintegrate, or break down; if they are not heated sufficiently, the treatment has no effect. Rivets may be heated in either a bath of sodium nitrate or in a hot-air furnace, with the former in more general usage.

The design of the sodium nitrate baths for heat-treating rivets should be such that the rivets do not come into contact with molten salt.

This equipment usually consists of a round tank or pot installed in a vertical electric furnace. The inside of the tank is fitted with a number of liquid-tight, vertical metal tubes from which the molten salt is excluded. The clearance between these metal tubes—which are about 2 to 2½ inches in diameter—should be at least ¼ inch in order to permit the salt bath to circulate freely around their outside surfaces. These tubes are closed at the bottom and open at the top to receive the individual rivet containers.

The top of the tank has a cover plate through which the tops of the metal tubes protrude. Figure 60 shows the tank and certain parts of the bath which we have discussed here. A close-fitting, insulated door covers the entire top of the tank and tubes. Thus, insofar as the transfer of heat to the rivets is concerned, this type of salt bath equipment constitutes an air furnace in which the heat is supplied by the molten salt.

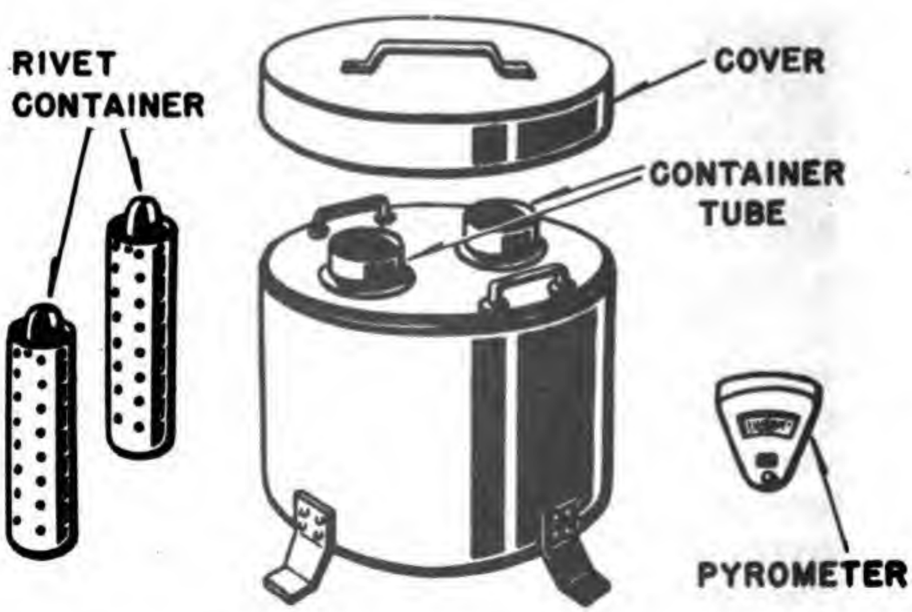


Figure 60.—Salt bath for rivets.

In order to transfer hot rivets from this salt bath to the quenching bath, perforated containers are fitted into the vertical tubes of the tank. These rivet containers should be short enough so that their tops are at least 4 inches below the surface of the salt bath.

A pyrometer is also required to eliminate all guesswork regarding the temperature of the rivet bath. The pyrometer should be of the automatic controlling and recording type—preferably the potentiometer type. Thermocouples for use in salt baths should be inserted in suitable protecting tubes.

HEAT-TREATING PROCEDURE

Place the rivets in the heated furnace and allow them to soak. (Soaking is holding the rivets of a given alloy at a certain temperature for a specified length of time to insure a uniform distribution of heat.)

For example, 17S rivets should be soaked at a temperature of 925° to 950° F. Rivets of 24S alloy should be soaked at a temperature of 910° to 930° F.

The soaking period depends upon the type of alloy, the diameter of the rivet, and the type of equipment used—and also whether or not the equipment is efficient. For the salt bath equipment just described, or for air furnaces provided with mechanical recirculation of air, the soaking time should not be less than 10 minutes. This soaking time does not apply, however, to the 24S rivets. The soaking time for 24S rivets should not be less than 30 minutes, excluding the time required for the entire rivet charge to reach the specified temperature. This is determined by placing a thermocouple within or near the bath.

When the rivets have soaked for the specified length of time, remove the rivet container from the furnace and immediately plunge the rivets into cold water. This quenching must occur within 10 seconds after the removal from the furnace. Failure to immediately quench the rivets will result in loss of corrosion resistance, the softened quality which makes them easy to drive, and their ultimate tensile strength.

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STORAGE AND USE OF HEAT-TREATED RIVETS

Heat-treated rivets begin to age-harden as soon as they are removed from the quenching bath. Age-hardening is the automatic return to hardness of the alloy in the rivet following heat treatment. This condition occurs spontaneously at room temperature and is very rapid during the first 24 hours. Age-hardening is considered complete at the end of 4 days.

Therefore, unless they are placed in a refrigerator or packed in dry ice, rivets must be driven almost immediately. 17S–T rivets must be driven within 1 hour after quenching unless kept at 32° F., in which case they can be headed after 1 day in such storage. If they are stored in dry ice or a refrigerator below 32° F., they can be driven within 1 week. 24S–T rivets must be driven within one-half hour, preferably 10 minutes after quenching. If packed in dry ice following quenching, they may be headed within a 24-hour period.

Once removed from refrigeration, rivets should not be returned, but placed in their proper storage place from where they may be reheat-treated. In general, heat treatment of rivets may be repeated as often as desired without injury to the rivets, provided the treatment is properly and carefully performed. However, an excessive number of reheating will result in the gradual hardening of the rivets. To reheat more than 15 times is considered excessive.

FLUSH RIVETING

Brazier-head rivets, because of their broad shallow heads, have been most used for external riveted construction. Nevertheless, even small rivet heads rising above the surface, when multiplied by the thousands, offer a considerable amount of resistance. Tests conducted by the National Advisory Committee for Aeronautics have shown that 9 rows of rivets running along the span of a wing and spaced from leading to trailing edge, increase the wing drag as much as 18 percent if compared with a smooth surface. Considering all exposed surfaces of an airplane that are studded

with protruding rivet heads, a speed of several miles an hour might well be lost.

Parasite drag, although present in all airplanes, can be reduced in several ways. Engineers have overcome a large part of rivet drag by using FLUSH RIVETING wherever possible at the more important points to maintain smooth surfaces. They have been generally used on the bottom of flying-boat hulls, where rivet heads produce not only air resistance but greatly increased water resistance in taking off. Along the leading edges of wings, de-icer installations also require flush-type riveting, and it is now often used on a large part of the upper camber.

There are two methods of flush riveting. Where heavier-gage aluminum-alloy sheet is used, the outside surface of the sheet may be countersunk at the rivet hole so that the rivet makes a stopperlike fit. Or more often, where lighter-gage materials are used, a depression or dimple is made by press countersinking in the sheet before or during assembly to seat the rivet head.

In both methods, the assembly head on the inside is formed in the usual way with a bucking iron, although the die in the riveting hammer is flat and smooth at the end rather than cup-shaped as for other types of rivets.

Since flush rivets are made with angles varying from 78° to 100°, it is necessary to countersink or dimple the metal to the angle of the rivet being used. The majority of work is performed with the 100° angle flush rivet. All countersinking and dimpling must be done with extreme care to avoid wrinkling.

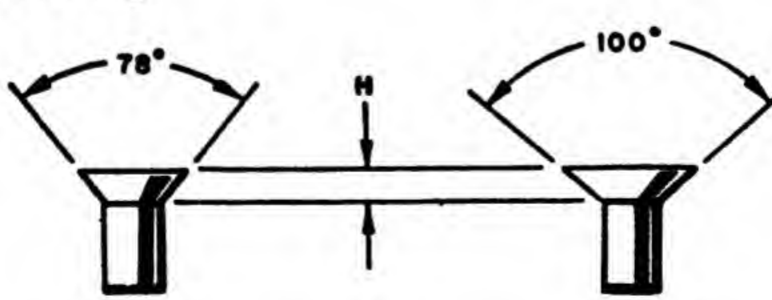


Figure 61.—Flush rivets.

The process used in preparing the sheet you use for flush riveting depends upon its thickness. Chart 6 explains the general recommendations applying to various methods.

Rivet diameter (inch)	Top sheet (t)	Under sheet (t)	Countersink (see code)
3/32	0.032 or greater		A
3/32	0.025 or less	0.051 or greater	B
3/32	0.025 or less	0.040 or less	C
1/8	0.040 or greater		A
1/8	0.032 or less	0.064 or greater	B
1/8	0.032 or less	0.051 or less	C
5/32	0.051 or greater		A
5/32	0.040 or less	0.072 or greater	B
5/32	0.040 or less	0.064 or less	C
3/16	0.064 or greater		A
3/16	0.051 or less	0.091 or greater	B
3/16	0.051 or less	0.081 or less	C

Chart 6.—Methods for countersinking.

DIMPLING

Dimpling is accomplished by pressing the metal around the rivet holes to the proper shape by use of dies. Since there are different angles of countersunk rivet heads, there must be a special set of dies for each angle as well as for each size of rivet.

The general practice is to use either a 78° or a 100° countersunk rivet, the latter being recognized as standard. In repair work, rivets whose countersink is less than 78° are replaced with 78° rivets, and those greater than 78° are replaced with the standard 100° rivet. In such cases it will be necessary to redimple or recountersink the hole to accommodate the new rivet. However, a machine countersunk hole should not be used or substituted for a previously dimpled or embossed hole.

In dimpling, the rivet hole is predrilled smaller than the rivet used because the hole will be enlarged in the dimpling process. Dimpling dies for light work may be set up in portable pneumatic or hand squeezers, as shown in (A) of figure 62. For repair work, the dies can be held by hand as in (B). If the dies are used with a squeezer, they must be adjusted accurately to the thickness of the sheet being dimpled.

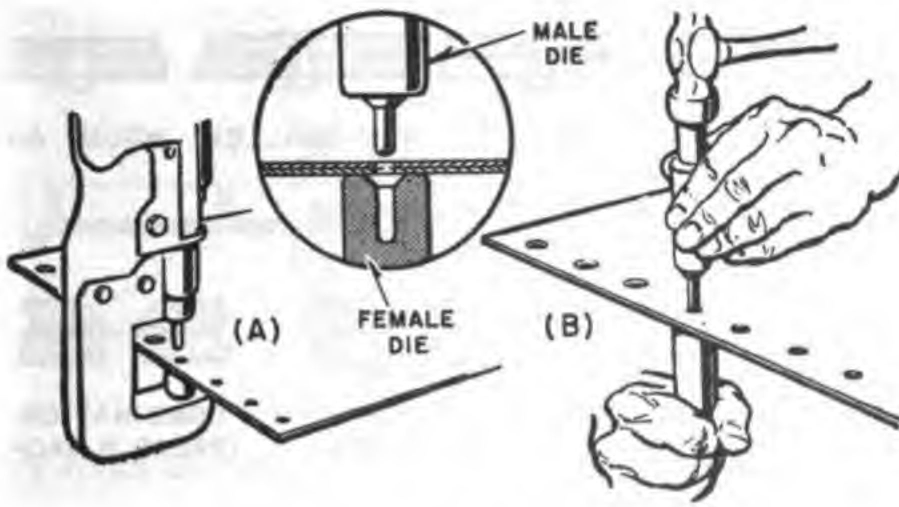


Figure 62.—Dimpling.

CUT COUNTERSINKING

For cut countersinking, predrill the rivet holes to rivet size and then countersink. The best tool for cutting the sheet for flush riveting is the stop type countersink shown in figure 63.

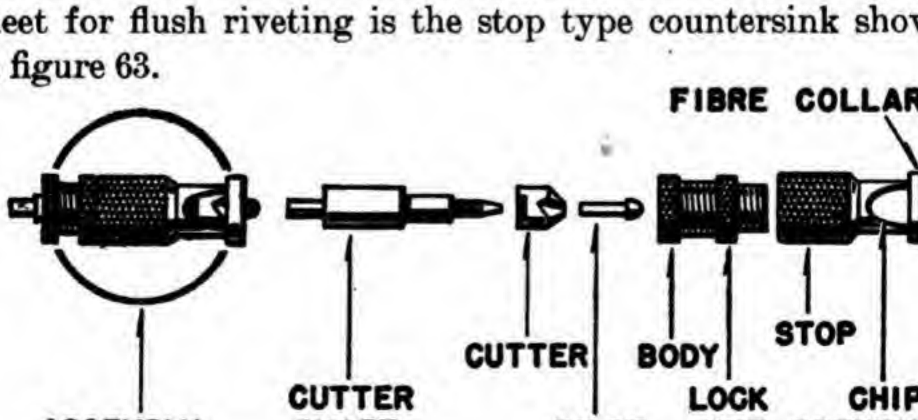


Figure 63.—Stop-type countersink.

The countersink should always be equipped with the fiber collar shown in figure 63, to prevent it from marring the aluminum.

A countersink such as the one just described is operated by a hand, air, or electric drill, which should operate below 2,500 r. p. m. The countersink must be sharp to avoid the vibration and chatter which result in imperfect holes. Figure 64 illustrates several effects of incorrect countersinking.

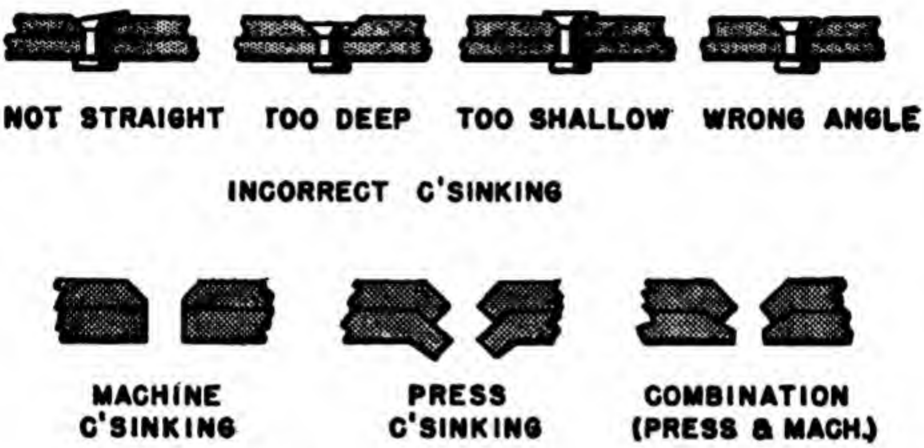


Figure 64.—Incorrect countersinking.

FLUSH RIVETING PROCEDURE

Flush rivets require greater care in driving and bucking than do ordinary rivets. The bucker and riveter must, in most cases, use signals to signify when the rivet is driven sufficiently or must be driven further.

The riveter's pressure on the gun against the rivet and the bucker's pressure against the bucking bar must be regulated so that the skin will not be stretched and produce a bulge in the sheet. Care must be taken to hold the sheet set flat against the rivet to prevent nicking or otherwise marking the skin. The actual driving of the rivet is similar to that used for ordinary rivets.

CHERRY RIVETS

Cherry rivets are a special type of mechanically expanded rivet, as may be seen in figure 65. Technically speaking, this

unit would be considered a fastener, but since it is classed as a rivet, we shall consider it in this phase of our discussion.

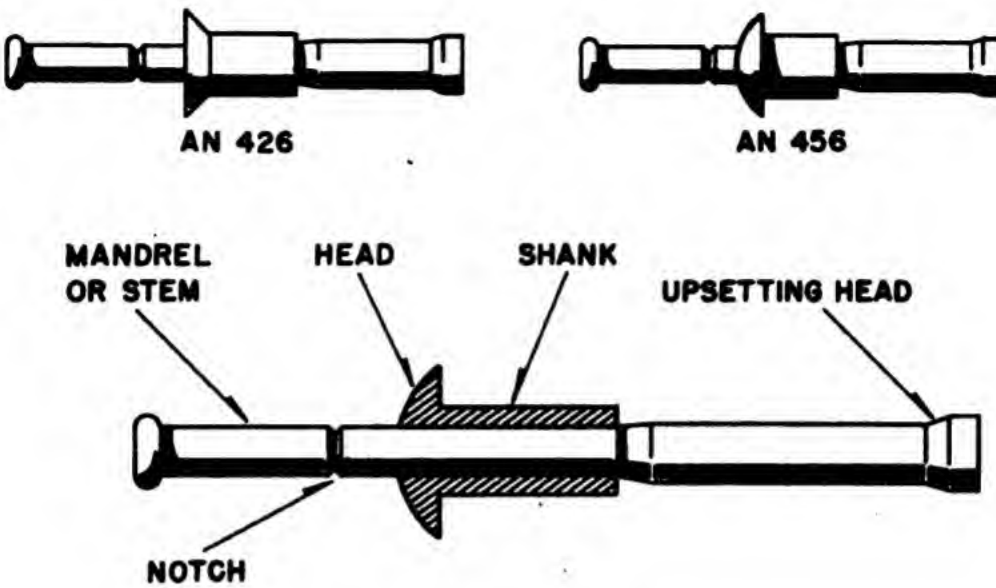


Figure 65.—Cherry rivets.

Cherry rivets are intended for use as permanent fasteners on surface of aircraft which are accessible from one side only, and are particularly well adapted for these installations because the shank can be expanded from the outside. Thus, one man can install cherry rivets, since a bucking bar is not required.

A cherry rivet is made in two parts. The rivet itself is composed of A17S–T, and has a hole through the shank and head. The stem, or mandrel, is made of 17S–T alloy. These two parts are assembled at the factory, and are delivered ready for use. As figure 65 illustrates, the stem extends beyond the rivet in each direction, and has a preformed head on either end.

To install the cherry rivet, place the movable jaw of the cherry rivet gun over the rivet stem. As pressure is applied, the gun pulls the stem end of the stem which has the upsetting head into the rivet, while holding the rivet head firmly against the sheet. By means of this process, the sheets are drawn together and a head is formed on the rivet shank.

The self-plugging cherry rivet is made with either brazier head (AN456) or a countersunk head (AN426). It is of two-piece construction and essentially the same as the hollow type with one important exception. The stem of the self-plugging type is longer—that is, it extends from both ends of the rivet. Figure 66 illustrates installation of the self-plugging cherry rivet.

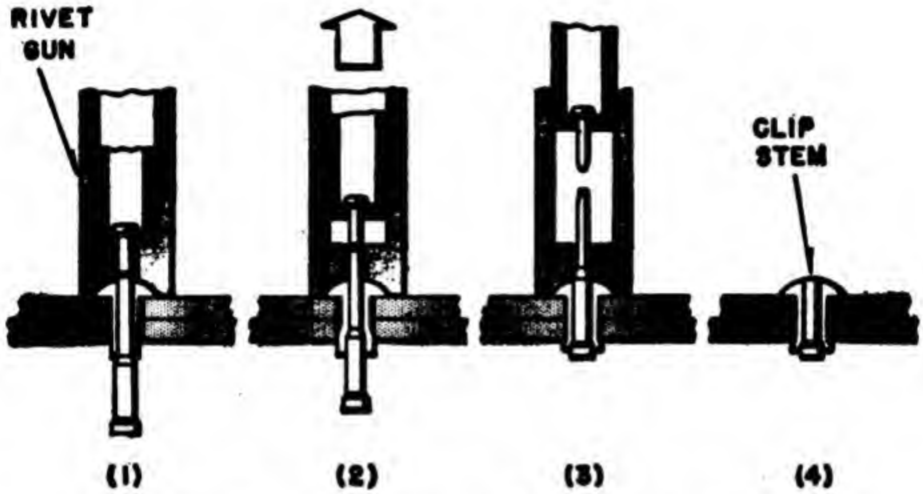


Figure 66.—Installing a self-plugging cherry rivet.

That portion of the stem of the self-plugging rivet which extends beyond the tail end of the shank is slightly larger than the hole in the rivet. When the rivet gun is operated, this larger portion of the stem is drawn into the rivet, completely filling it with a permanent plug. A tulip head is thus formed on the blind side of the rivet.

Continued pulling on the stem with the rivet gun causes the stem to break as in the third drawing of figure 66, leaving a broken and protruding stem above the manufactured head of the rivet. This stem must be trimmed flush.

The series numbers of the self-plugging rivets are shown in figure 65. LS1126 is the countersunk-head type, and LS1127 is the brazier-head type.

Cherry rivets are made in three sizes—$\frac{1}{8}$, $\frac{5}{32}$, and $\frac{3}{16}$ inch. Rivets of each of these diameters can be obtained in grip lengths for all material thicknesses from 0.30 to 0.0391 inch. The cherry rivets of the self-plugging type vary in

lengths by thirty-seconds of an inch from 1/16 to 3/16 inch.

The size of rivet to be used may be decided by determining the combined thicknesses of the sheets to be fastened together and then selecting a rivet with a nominal grip length nearest that thickness. There can be a considerable leeway in selecting the size to use, since cherry rivets will handle material which is 1/64 inch (0.016 inch) thicker or 3/64 inch (0.047 inch) thinner than the nominal grip length. The material thickness table (chart 7) explains this principle.

Rivet code no.	Nominal	Minimum	Maximum
2	0. 063	0. 030	0. 077
4	. 125	. 078	. 140
6	. 1875	. 141	. 203
8	. 25	. 204	. 265
10	. 3125	. 266	. 328
12	. 375	. 329	. 391

Chart 7.—Material thickness table.

For example, if the sheets to be fastened have a combined thickness of 0.080 inch and are not dimpled, a rivet with a 1/8-inch nominal grip should be used—that is, a No. 4 rivet. If the combined thickness is 0.75 inch, a rivet with a No. 2 grip length should be used.

The method for figuring the proper grip length where countersunk rivets are to be used with dimpled sheets is somewhat different. Take the total thickness of the sheets, plus the amount which the dimple extends beyond the inside surface, as shown in figure 67. Assume that the sheets are 0.052 inch in thickness and that the dimple extends 0.038 inch on the inside of the work. The total grip length would therefore be 0.090 inch. Thus the required rivet would be LS1126–4–4, because the range of thicknesses covered by this rivet covers the thickness 0.090 inch, which has been computed.

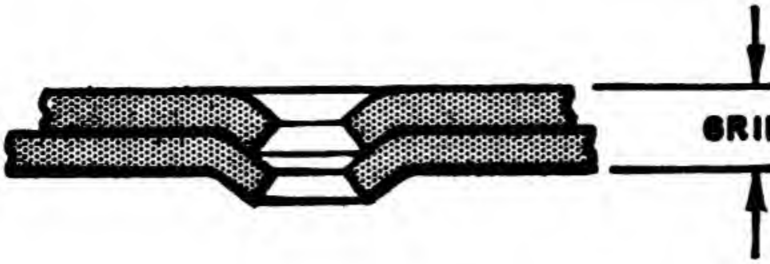


Figure 67.—Figuring grip length.

Uses of Cherry Rivets

Navy Specification Order R–23 states the limitations on the use of cherry rivets:

> The rivets for blind attachment covered by this specification are intended for use in fastening primary, secondary, or nonstructural parts on naval aircraft, with the exception of CONTROL SURFACE HINGE BRACKETS, WING ATTACHMENT FITTINGS, LANDING GEAR FITTINGS, FIXED TAIL SURFACE FITTINGS, or in other similar heavily stressed locations; or in floats, hulls, or tanks.

In regard to the sizes of cherry rivets to be used, Navy Letter A3n–E–252–HMS, states the following:

> Sizes approved: LS1126, LS1127, and LS1128. If you replace another rivet with a cherry rivet, the cherry rivet used shall be one size larger than the rivet it replaces. But if you are simply replacing another cherry rivet, you may replace it size for size.

From the above specification it may be seen that cherry rivets are somewhat weaker than AD rivets of the same nominal diameter. They are restricted in use to the extent stated and must be of a larger size when replacing ordinary rivets.

CHERRY RIVET GUNS

Figure 68 illustrates the two types of guns used for cherry rivets—the hand gun shown in (A) and the pneumatic gun seen in (B).

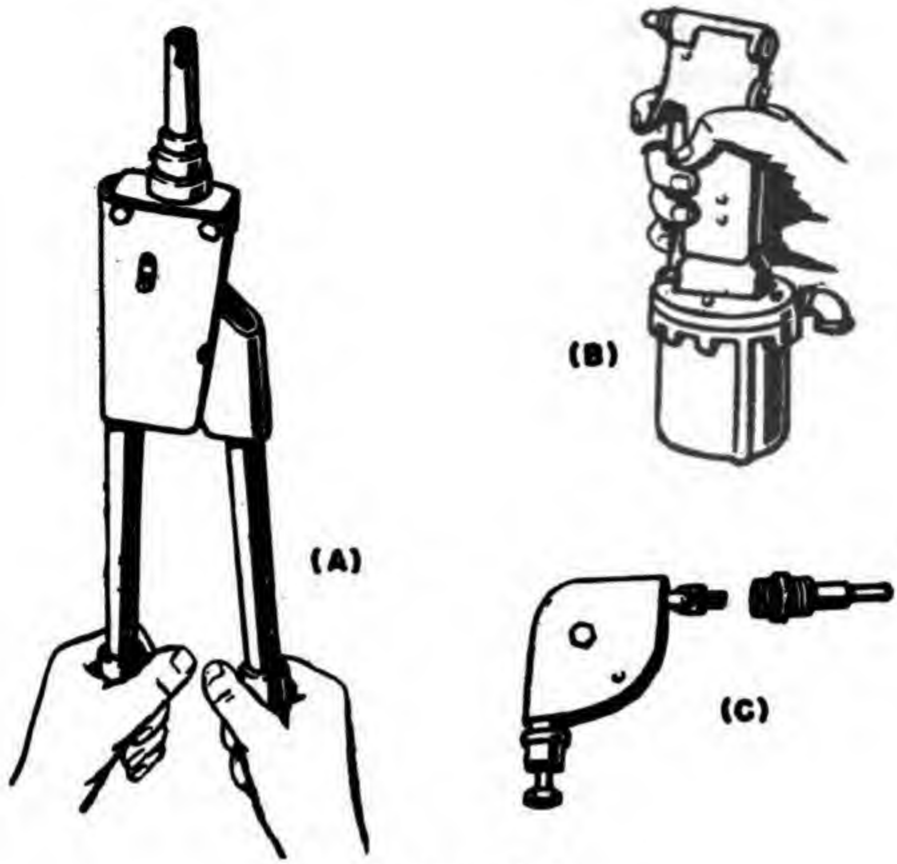


Figure 68.—Cherry rivet guns.

Both guns have the same essential parts—an inside drawbolt which pulls the stem of the cherry rivet, and on outer sleeve over the drawbolt, which exerts a steady pressure on the rivet head. The combination of these two units forms the pulling head. These pulling heads are readily interchangeable.

The pulling force on the hand gun is exerted by means of a ratchet, and the operation is similar to that of a car jack. Several short strokes of the movable handle will pull in the rivet and break the stem. The pneumatic guns accomplish the same result by means of compressed air.

RIVETING PROCEDURE

In drilling holes for cherry rivets, care should be taken to have the hole at right angles to the sheets which are to be

fastened together. Chart 8 furnishes the recommended drill sizes which match the various diameters and types of self-plugging cherry rivets.

Series	Diameter	Hole size	Drill size
LS-1126 and LS-1127	1/8	0.128 to 0.132	30
LS-1127	5/32	.160 to .164	20
	3/16	.192 to .196	10
LS-1128	1/8	.137 to .141	29
	5/32	.177 to .181	16
	3/16	.206 to .210	5

Chart 8.—Drill sizes.

In regard to the drilling of holes, Navy Letter Aer-E-252-HMS states the following:

> Cherry rivets shall be installed in rivet holes that approximate the shank diameter of the rivet as closely as possible.
>
> In cases of dimpled assemblies, the rivet holes shall be drilled after the sheets are dimpled at the pilot holes.

After drilling, the holes should be burred and the chips cleaned from between the sheets. Preparatory to riveting, sheet clamps should be used at reasonable intervals.

When all preparations are completed and the proper-size rivet has been selected, a pulling head of the corresponding size is put on the gun. The rivet may either be inserted into the drilled hole or into the pulling head. In either case, before the rivet is bucked, care should be taken to see that the rivet stem is properly placed in the center of the draw-bolt. It is equally important to see that the gun is at right angles to the sheets being riveted.

If the hand gun is used, hold the stationary handle in one hand and give the movable handle several strokes with the

other, which should be sufficient to pull the stem into the rivet shank, breaking the stem above the rivet head. Identical results are obtained with the pneumatic gun by squeezing the trigger in the same way that ordinary pneumatic riveters are operated.

The portion of the stem protruding above the rivet is cut off flush with the manufactured head, using flat-ground nippers. As a final step, Navy Letter Aer–E–252–HMS advises that the plug end shall be coated with a 10 percent solution of chromic acid.

EXPLOSIVE RIVETS

Explosive rivets are a special type of blind fastener designed especially for use on those jobs in aircraft construction and repair where the back of the rivet cannot be reached with a buckling bar. Explosive rivets are similar in appearance to a regular aluminum alloy rivet, but are made with a cavity in the shank which contains the explosive charge, as shown in figure 69.

The end of the cavity containing the charge is sealed with a watertight coating. When a riveting iron has been heated to the proper temperature and its tip is applied to the rivet head, the charge explodes, forming a clinched head which is 15 to 30 percent larger than the original shank diameter, as figure 69 demonstrates.

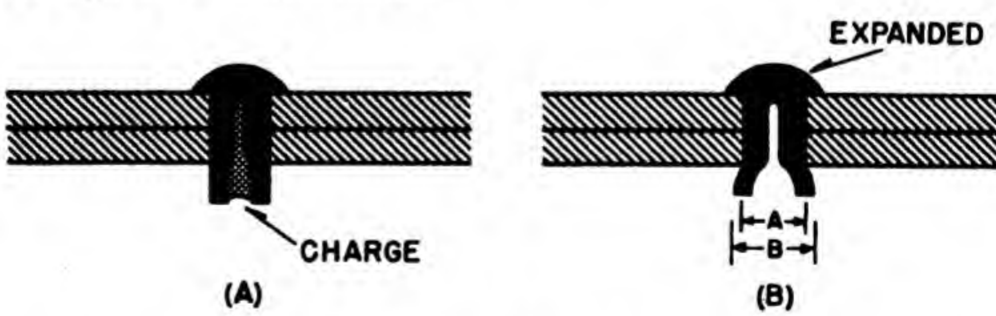


Figure 69.—Explosive rivets.

Explosive rivets are made from 17S–T aluminum alloy, and are ready to use as received. No heat treatment or refrigeration is necessary, but the rivets should be stored in a cool place.

At present, explosive rivets are manufactured in two sizes—$\frac{5}{32}$ and $\frac{3}{16}$ inch, with the brazier head and the countersunk head. The countersunk head is available in three different degrees of countersink—78°, 100°, and 115°. For repair work on naval aircraft, only the brazier head and the 100° countersunk head are authorized.

Grip length or total thickness to be riveted		Proper size (If $\frac{1}{8}$ inch diameter is indicated)	Brazier head (If $\frac{5}{32}$ inch diameter is indicated)	Rivet to use (If $\frac{3}{16}$ inch diameter is indicated)	Color of rivet
Minimum (inch)	Maximum (inch)				
0.025	0.044	DR-127A-4			Yellow.
.045	.064	DR-127A-6	DR-173A-6		Black.
.065	.084	DR-127A-8	DR-173A-8	DR-204A-8	Red.
.085	.104	DR-127A-10	DR-173A-10	DR-204A-10	Blue.
.105	.124	DR-127A-12	DR-173A-12	DR-204A-12	Brown.
.125	.144	DR-127A-14	DR-173A-14	DR-204A-14	Yellow.
.145	.164	DR-127A-16	DR-173A-16	DR-204A-16	Black.
.165	.184	DR-127A-18	DR-173A-18	DR-204A-18	Red.
.185	.204	DR-127A-20	DR-173A-20	DR-204A-20	Blue.
.205	.224		DR-173A-22	DR-204A-22	Brown.
.225	.224		DR-173A-24	DR-204A-24	Yellow.
		Actual shank diameter =0.127″ + 0.001″-0.000″	Actual shank diameter =0.173″ ± 0.0005″	Actual shank diameter =0.204″ ± 0.0005″	

Chart 9.—Grip lengths of brazier-head rivets.

Explosive rivets are made in three different shank diameters—$\frac{1}{8}$, $\frac{5}{32}$, and $\frac{3}{16}$ inch.

Each shank diameter and type of head is made in various grip lengths—from 0.020 inch in the $\frac{1}{8}$-inch rivet to a maximum of 0.240 inch in the $\frac{5}{32}$- and $\frac{3}{16}$-inch diameters. Charts 9 and 10 show the actual grip lengths which are available.

Grip length or total thickness to be riveted		Proper size countersunk rivet to use			Color of rivet
Minimum (inch)	Maximum (inch)	If $\frac{1}{8}$ inch diameter is indicated	If $\frac{5}{32}$ inch diameter is indicated	If $\frac{3}{16}$ inch diameter is indicated	
0.045	0.064	DR-134-100 † -6	....	....	Black.
.065	.084	DR-134-100-8	DR-173-100 † -8	....	Red.
.085	.104	DR-134-100-10	DR-173-100-10	DR-204-100†-10	Blue.
.105	.124	DR-134-100-12	DR-173-100-12	DR-204-100-12	Brown.
.125	.144	DR-134-100-14	DR-173-100-14	DR-204-100-14	Yellow.
.145	.164	DR-134-100-16	DR-173-100-16	DR-204-100-16	Black.
.165	.184	DR-134-100-18	DR-173-100-18	DR-204-100-18	Red.
.185	.204	DR-134-100-20	DR-173-100-20	DR-204-100-20	Blue.
.205	.244	....	DR-173-100-22	DR-204-100-22	Brown.
.225	.244	....	DR-173-100-24	DR-204-100-24	Yellow.
		Actual shank diameter = 0.134" + 0.001"-0.000"	Actual shank diameter = 0.173" ± 0.0005"	Actual shank diameter = 0.204" ± 0.0005"	

†100° countersunk indicated. In $\frac{1}{8}$ inch diameter 78° and 115° countersunk heads also available.

Chart 10.—Grip lengths of countersunk rivets.

The grip of the rivet indicates the total thicknesses of the metal it will rivet together.

Code for Explosive Rivets

The code for these rivets is made up of a series of numbers and letters which indicate the type, the actual shank diameter, the type of head (and the degree of countersink if it is of that type head), and the grip in hundredths of an inch.

Figure 70 (A) explains the meaning of a code number, in this instance an explosive rivet designated as DR–127 A–6. DR indicates a DuPont rivet; the 126, the diameter in thousandths of an inch (in this case, a $\frac{1}{8}$-inch nominal diameter); the A that the rivet has a brazier head; and the final 6 indicates the grip length in hundreths of an inch.

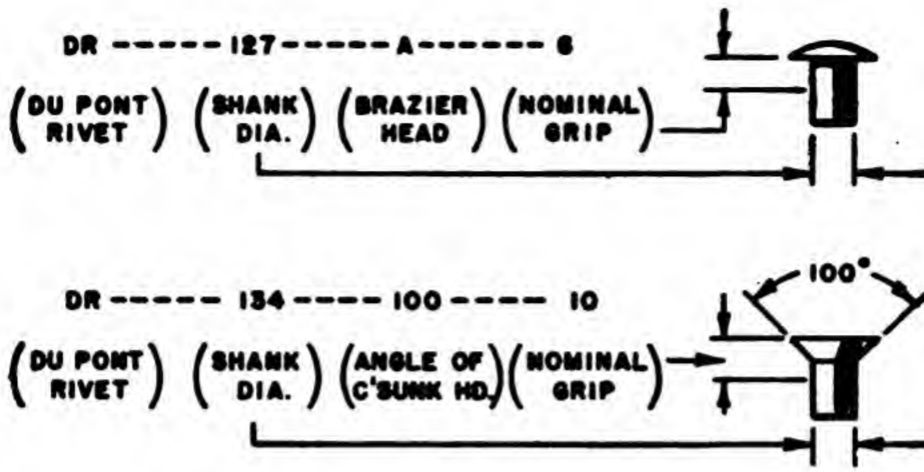


Figure 70.—Code numbers for explosive rivets.

Another example of the code is shown in (B) of figure 70. Here the number DR–134–100–10 means that the rivet is a DuPont product, 0.134 inch in shank diameter, has a 100° countersunk head, and a grip length of 0.10 inch.

EXPLOSIVE RIVET GUNS

The riveting gun for explosive rivets is an electrically heated iron, very similar to an electric soldering iron, as shown in figure 71. Tips for this iron are made of pure silver.

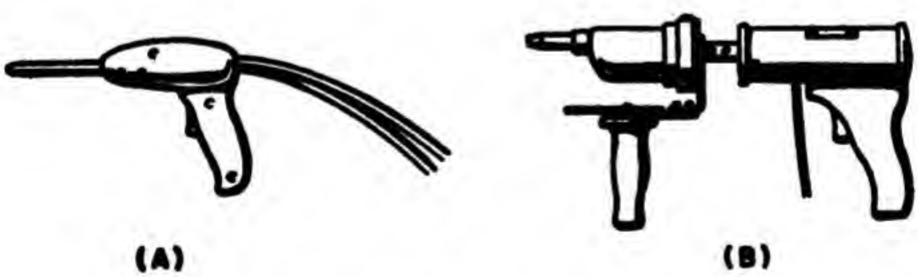


Figure 71.—Explosive rivet gun.

Tips for brazier and countersunk head rivets of different sizes are available and readily interchangeable. When the iron is heated to the correct temperature and the tip brought in contact with the head of the explosive rivet, the charge

explodes, forming a barrel-shaped head which is 15 to 30 percent greater than the original shank diameter.

RIVETING PROCEDURE

One of the primary factors in using explosive rivets is the selection of the correct tip for the type of rivet to be used. For example, a tip with the number 4–BSS4 would be used in a No. 4 gun, and is for use on a brazier head explosive rivet, $\frac{4}{32}$ inch in diameter.

Figure 72.—Installation of explosive rivets.

Set the knob of the wattage regulator to the correct temperature for the rivet being used. Experience will indicate the correct setting, but in general, the following procedure can be used when a No. 3 or 4 iron is employed:

Rivets shorter than 8 grip length—set on low.

Rivets longer than 18 grip length—set on high.

Rivets between these grip lengths—set the regulator to a higher or lower position according to the length of the rivet.

Preheat the iron for 20 to 30 minutes before using it, then apply the tip of the riveting iron.

Use sufficient pressure on the iron to insure good contact, and continue pressing until the rivet explodes with a loud report. Then remove the iron immediately following expansion. If the rivet fails to expand in 1½ to 6 seconds, readjust the temperature regulator up or down accordingly.

Remove and replace all rivets that do not expand within the correct interval of time. Rivets that fail to expand the first time will usually give a weak expansion when reheated.

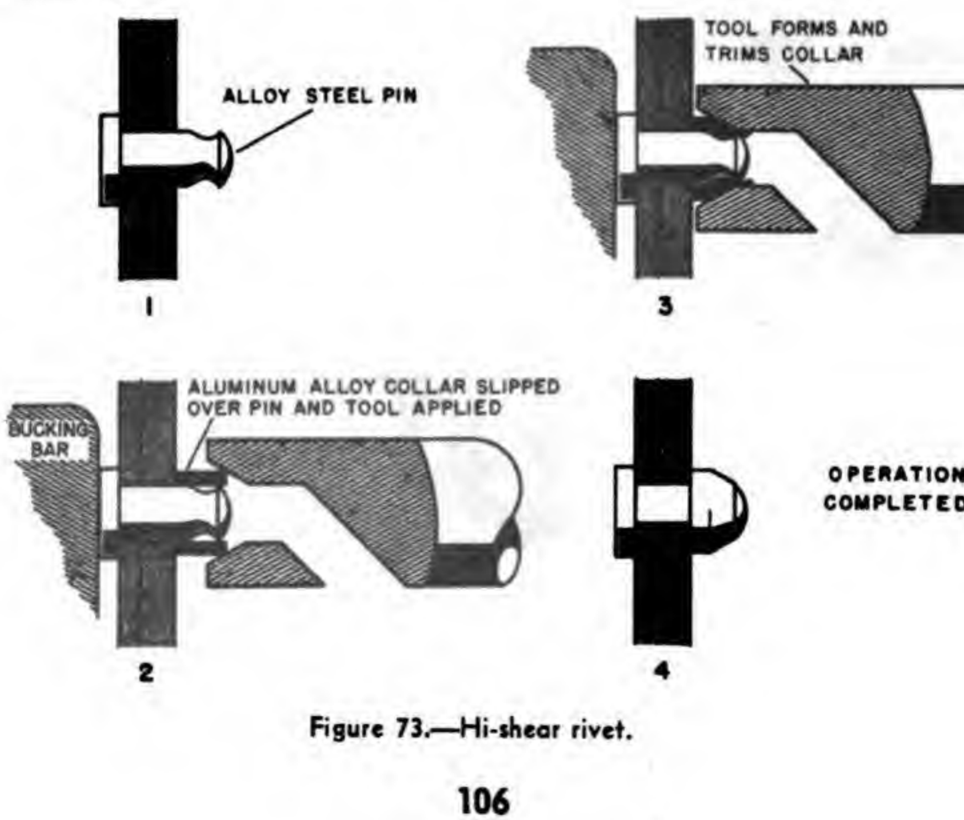


Figure 73.—Hi-shear rivet.

HI-SHEAR RIVETS

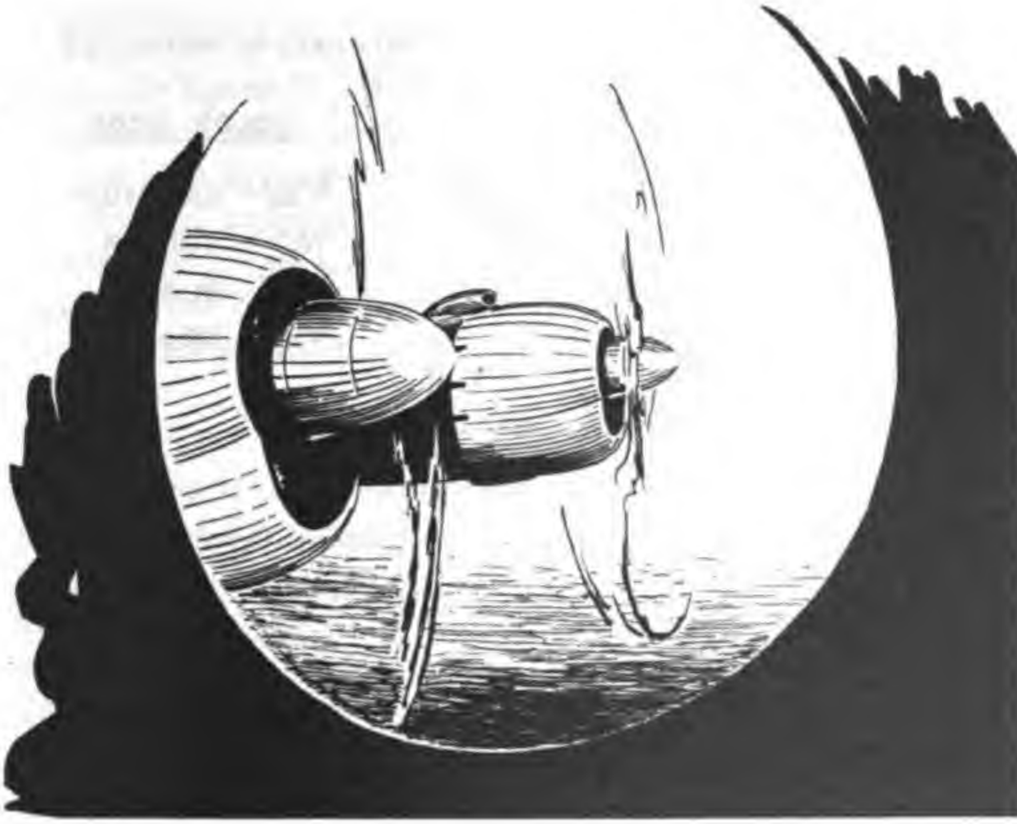
Hi-shear rivets consist of two parts—the alloy steel pin and the aluminum alloy collar. These rivets have the same shear strength as that of comparable sizes of AN hexagon head bolts or steel screws, but the average complete Hi-shear rivet weighs only two-fifths as much as the average bolt, nut, and washer.

The head of a Hi-shear rivet pin is smaller than the head of a bolt of the same strength, because these rivets require no provision for turning. The collar is smaller than a nut because no thread, hexagon shape, or locking device is required.

Installation time is approximately one-fifth of that required for bolts, and no special technical skill is necessary.

QUIZ

1. For what riveting job would you use a roundhead rivet?
2. What type rivet would you use for riveting thin sheet exposed to the slip stream?
3. What alloy would a rivet with two raised bars on the head be made of?
4. How much larger than the rivet should the drill be when drilling holes for sheet plate rivets?
5. What type rivet would you use for parts fabricated from 2S and 3S aluminum alloy?
6. What length rivet should you use for riveting two ⅛-inch sheets together using a rivet with a shank diameter of ⅛-inch?
7. In general what should the height of the "bucktail" be?
8. As a general rule what is the minimum spacing of rivets?
9. If you are riveting a piece of $\frac{1}{16}$ sheet to a ¼-inch stringer, what is the minimum distance that the rivet should be spaced apart?
10. What type riveter would you use on the trailing edges and root sections of a wing?
11. What alloy is used for explosive rivets?
12. What advantage do high-shear rivets have over AN hex-head bolts or steel screws?



CHAPTER 6

SHEET-METAL FASTENING DEVICES

With the introduction of sheet metal in aircraft construction, a need for fasteners to hold the sheets tightly together and in alinement prior to fittting, drilling, and riveting arose. Several types of fasteners have been developed, each of which possesses certain advantages or disadvantages, depending on the specific need.

CLECO FASTENERS

Various types of fasteners have been developed to meet the need for temporary fastening of one sheet to another or to structural parts during the process of repair and assembly. One of the most convenient of temporary fasteners, introduced to meet the demand for faster methods of production, is the spring, or Cleco sheet metal holder, illustrated in figure 74.

Figure 74.—Cleco fastener.

The Cleco fastener is a small metal cylinder through which extends a spring-actuated, self-locking plunger, with a fiber cushion on the underside to prevent marring of the metal surface. These devices are furnished in sizes from $\frac{3}{32}$ to $\frac{3}{16}$ inch, and are colored for easy identification, according to the code shown in figure 74.

Since these holders exert a pressure of 50 pounds, and do not loosen under vibration, they can be used effectively for holding sheet metal in place when drilling or riveting.

MACHINE SCREWS

The machine screw and nut were among the first devices used to provide temporary fastening of aircraft sheet metal parts. Machine screws, pictured in figure 75, make secure fasteners, but require more time to apply and remove than some of the newer fasteners.

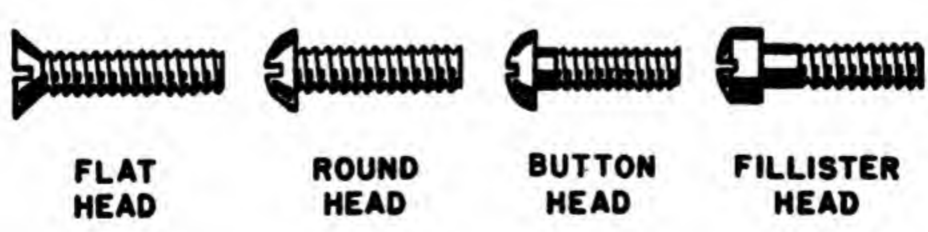


Figure 75.—Machine screws.

The screw is manufactured with the various head shapes shown in figure 75. The truss head is sometimes called the brazier or button head. The fillister head may be obtained with a hole drilled through the head at right angles to the slot for the purpose of safety wiring.

Although these screws are made of several materials, those most generally used in aircraft work are made of cadmium plated steel or anodized aluminum alloy.

Sizes

The sizes of machine screws are determined by the outside diameter of the threads, by the number of threads per inch, and by the length. The diameters range from 1 to 10 gage, plus $\frac{1}{4}$-, $\frac{5}{16}$-, and $\frac{3}{8}$-inch fractional diameters. Screws are made with National Fine (N. F.) and National Coarse (N. C.) threads. The number of threads per inch will vary for different screws, the most common for aircraft use having 32 threads to the inch.

When a machine screw is referred to as 8–32, 10–32, and so on, it simply means a screw with a No. 8 or No. 10 diameter, having 32 threads per inch. The standard sizes most generally used are 4–40, 6–32, 8–32, and 10–32.

Machine screws are obtainable in various lengths designated in sixteenths. Aluminum alloy screws of the fine thread series that are smaller than 10–32 should NOT be used because the threads are easily stripped.

A–N Specifications for Machine Screws

The code number for machine screws is as follows:

AN500C–6–7 — Length in 16ths of an inch (in this case, 7/16 inch).
- 6 — Diameter No. 6.
- C — Corrosive resistant steel (Cadmium plated steel).
- 500 — Part Number Coarse thread.
- AN — Army and Navy.

AN510D–8–5 — Length, 5/16 inch.
- 8 — Diameter No. 8.
- D — Aluminum alloy.
- 510 — Part Number Fine thread.
- AN — Army and Navy.

Uses for Machine Screws

Machine screws should not be used in primary airplane structures, or for attachment of superstructure or accessories where their failure would result in danger to personnel. In the absence of Cleco sheet fasteners or other suitable temporary fasteners, machine screws may be used to hold sheets together during assembly. These screws are also used with various types of safety lock nuts, as shown in figure 76, in assemblying inspection plates, temporary patches, and connecting skin to certain parts of the airplane structure.

Figure 76.—Safety lock nut.

Machine screws must be sufficiently long to extend through the assembled parts until two threads appear on the opposite side to insure utilizing the complete bearing strength of the screw and nut or tap strip.

PARKER KALON SCREWS

Parker Kalon, called "PK's," screws are made of very hard steel which is plated to prevent corrosion, and are designed to tap their own threads in softer aluminum alloy.

There are two types of Parker Kalon screws—type A, designed for joining sheet not heavier than 0.050 inch, and type Z, for joining light and heavy sheet from 0.15 to 0.203 inch in thickness. These devices are illustrated in figure 77.

Figure 77 also shows the more common head styles of Parker Kalon screws, although they may be obtained with

recessed Phillips' heads. In general, the blunt Z type is most satisfactory because of its greater range of use, although the A type is even more satisfactory if the alinement of the holes is difficult. These screws are available in varying lengths to meet the needs of particular sheet thicknesses.

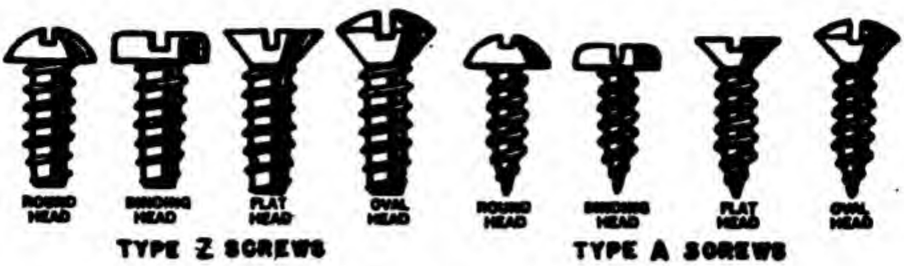


Figure 77.—Parker Kalon screws.

The hole size for insertion of these screws may be determined by considering the nature, hardness, and thickness of the metal to be fastened. Chart 11 describes this detail.

No.	Diameter	Metal thickness	Diameter of hole	Size of drill
4	0. 112	0. 015 to 0. 064	0. 076 to 0. 089	48 to 43
6	. 137	. 015 to . 064	. 101 to . 106	38 to 36
8	. 163	. 025 to . 128	. 116 to . 149	32 to 25
10	. 186	. 031 to . 162	. 140 to . 162	28 to 21

Chart 11.—Hole sizes for Parker Kalon screws.

Uses for Parker Kalon Screws

Parker Kalon screws are often used to hold sheets of metal together temporarily during construction and also for emergency repairs on skin surfaces. This type of screw is used for permanent fastenings of instrument panels and cabin linings and with various plastic materials.

Self-tapping screws used in aluminum alloy should be installed with a phenolic or aluminum washer between the head of the screw and the alloy so that the screw will not burr the sheet. Both washer and screw should be coated with a zinc chromate base to form a complete seal and prevent the entrance of moisture.

ANCHOR NUTS

The anchor nut, or plate nut, as it is sometimes called, is a self-locking nut with lugs for fastening it to the structure, usually by riveting. The types most often used are shown in figure 78. The self-locking device of the plate nut consists of a rubber or fiber collar which is held securely to the top of the nut.

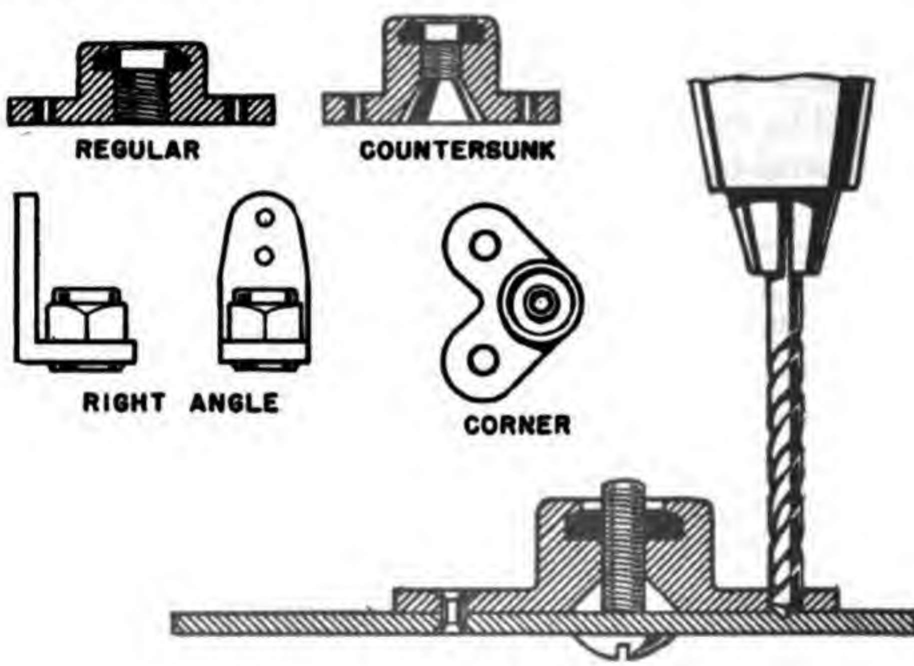


Figure 78.—Installing anchor nuts.

The plate nuts used in aircraft work are aluminum alloy with an anodic finish, or of cadmium-plated steel. The most common sizes of the plate nuts are Nos. 6–40, 6–32, 8–36, 8–32, and 10–32, the figures indicating the size and number of threads per inch in the nut. The rivet holes in the lug (flange) are usually 0.098 inch (No. 40 drill).

The use of plate nuts is usually limited to structures which are frequently removed and thus must be quickly detached. Use of a plate nut as a fastener makes for a solid joint in spite of these conditions. An example of such use may be found in sheet metal inspection covers.

In installing anchor nuts, it is most important to rivet the lugs so that the hole through the nut lines up with the screw hole. Otherwise it will be impossible for the screw to engage the threads of the nut. The best method of installing the anchor nut of the lug type is to insert the screw through the hole in the sheets to be secured and screw the anchor nut down tight then drill holes for rivets.

CHANNEL GANG NUTS

The parts of an airplane structure that must be frequently removed in field service—such as the floor plates of flying boats—are installed with channel gang nuts. This fastener is also known as a strip plate.

As the name implies, channel gang nuts are simply U-type channels constructed so that the anchor nuts are inserted and held in position by the top ledge of the channel, as may be seen in figure 79.

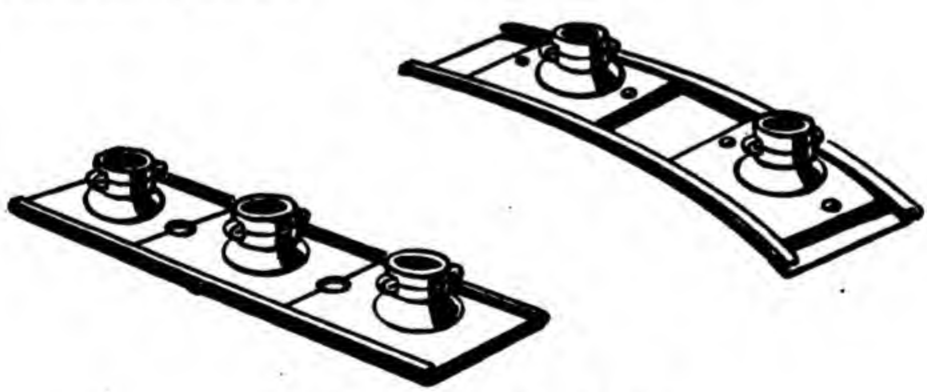


Figure 79.—Channel gang nuts.

If the nuts are placed end to end, each end of the channel is closed so that the nuts cannot slip out. In using these channels, time is saved by not having to rivet each anchor nut into place. The channel, however, must be held in position by an adequate number of rivets.

Quite frequently, upon repeated removal of the structures, one of the nuts in or near the center of the channel will become stripped and require replacement. If the channel cannot be spread enough to remove the damaged nut, the nuts must be removed from one end until the bad nut is reached and replaced with a new one. This method is used if the nuts are end to end.

The nuts are secured in the channel in various ways. Figure 79 shows two types of gang channels. One shows the anchor nuts jammed end to end, the other demonstrating the manner in which they may be secured by a dimpling process.

DZUS FASTENERS

Dzus fasteners are made of heat-treated and cadmium-plated nickel steel, and consist of a grommet, spring, and stud, the grommets being composed of aluminum. These devices are used to fasten inspection covers, cowls, fairing, flooring, paneling, and similar units.

Dzus fasteners are easily installed. They can be operated quickly, yet hold securely when locked. They have no loose parts to be lost, are adaptable to many installations, and very neat in appearance. These fasteners, sometimes called studs, are available with several different shaped heads and dimensions to meet individual requirements. Figure 80 illustrates several types.

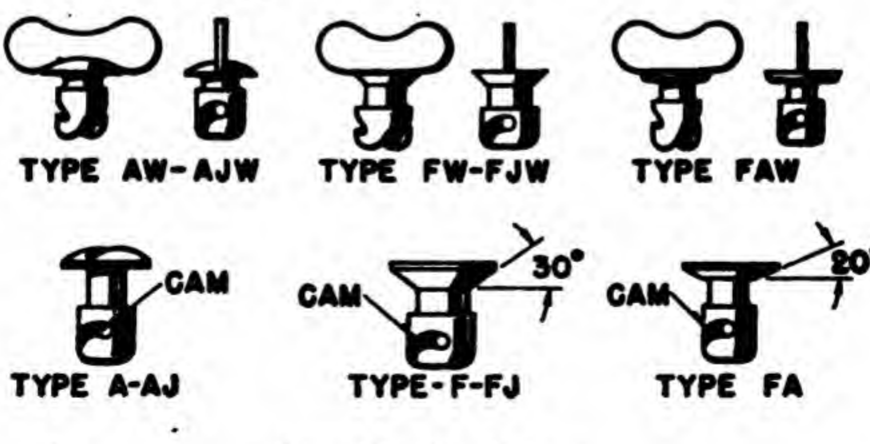


Figure 80.—Dzus fasteners.

Type A has an oval head. Types F and FA have flush heads, but type FA has a head with a rounded edge. Type HF has a hexagonal head. If the letter J is added, as AJ and FJ, it indicates that the fastener has a longer undercut below the head than types A and F.

If the letter O follows in the symbol—as AO, for example—it designates a fastener with no undercut so that it may be removed when unlocked. This type is not commonly used, but is available if required.

The letter W in the symbol indicates that a wing is attached to the head.

The first figure after the typed letters indicates the body diameter of the fastener in sixteenths of an inch. The number following the dash (–) gives the length (L) of the fastener in hundredths of an inch.

All standard springs are designated by the letter S and the figure following this letter indicates the size of the fastener with which it is used. The number after the dash (–) shows the height of the spring. Type S3–200 is a standard spring for use with a No. 3 fastener and is 0.200 inch high. Different spring heights are available for each fastener.

There are special springs available for installation in box corners and panels subject to horizontal or vertical movement, as shown in figure 81.

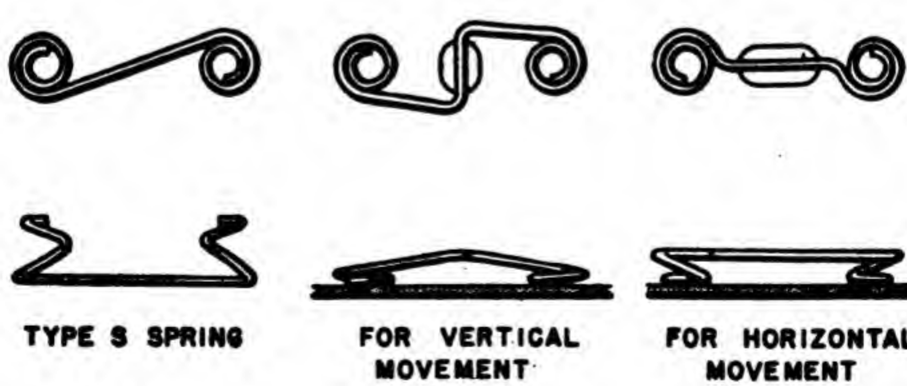


Figure 81.—Special springs.

Standard grommets are designated similar to springs, except that they are preceded by the letters GA and GF. For example, a symbol such as GA6–½–375, indicates a grommet to be used with a type A or AJ, 6–½ fastener with an overall length of 0.375 inch.

Figure 82 furnishes complete data relative to tools available for the different sizes and types of fasteners, and figure 83 illustrates installation instructions and a key to proper tools, drill sizes, and so on.

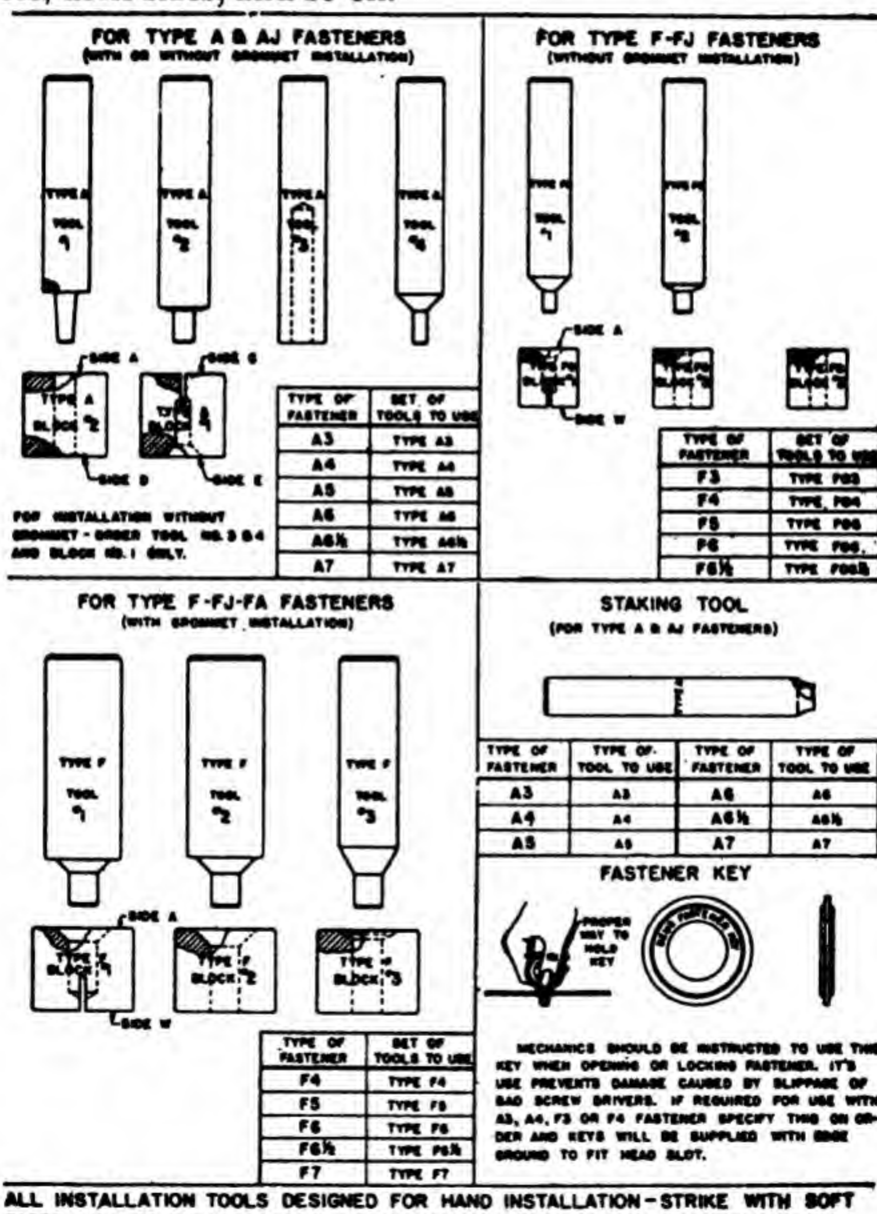


Figure 82.—Tools for installing Dzus fasteners.

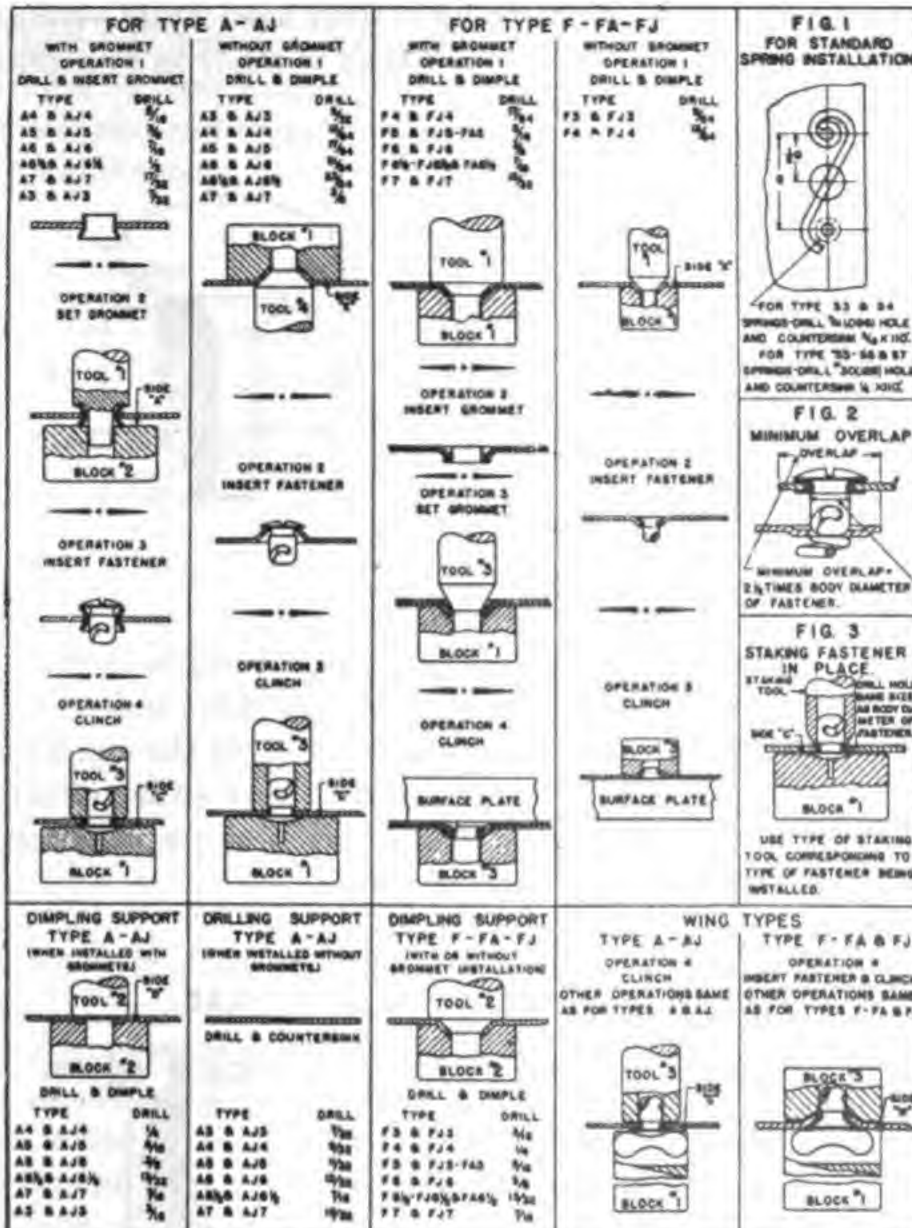


Figure 83.—Installation instructions.

RIVNUTS

The rivnut is a rivet-type nut—an internally threaded and counterbored tubular rivet that can be headed blind. These devices are machined from 53S–W, one of the most corrosive-resistant of the aluminum alloys. Rivnuts are of one-piece construction, anodized, and ready for use as received.

Rivnuts are classified according to their head styles—countersunk, or flat. The countersunk head is made in two general shapes shown in figure 84.

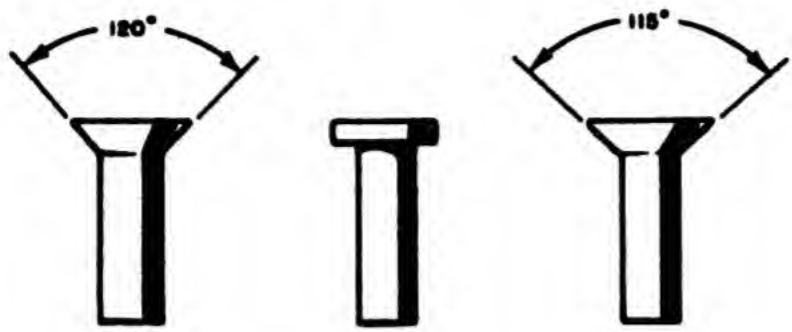


Figure 84.—Rivnut heads.

Both countersunk and flat head styles are made in three sizes—No. 6–32, 8–32, and 10–32, these numbers indicating the diameter and number of threads per inch of the machine screw that fits into the rivnut. Rivnuts have either closed or open ends, as demonstrated in figure 85 and are available with or without keys.

Figure 85.—Rivnuts with closed and open ends.

The grip range of the rivnut is the maximum and the minimum total thickness of a sheet through which a rivnut may be successfully headed, and is indicated by the marks on the head of the nut. Chart 12 shows specific grip ranges for the various sizes of flat head rivnuts.

Their use has now expanded enormously. The open end rivnut is used extensively in aircraft repair work, whereas the closed end type is used in such places as sealed flotation compartments.

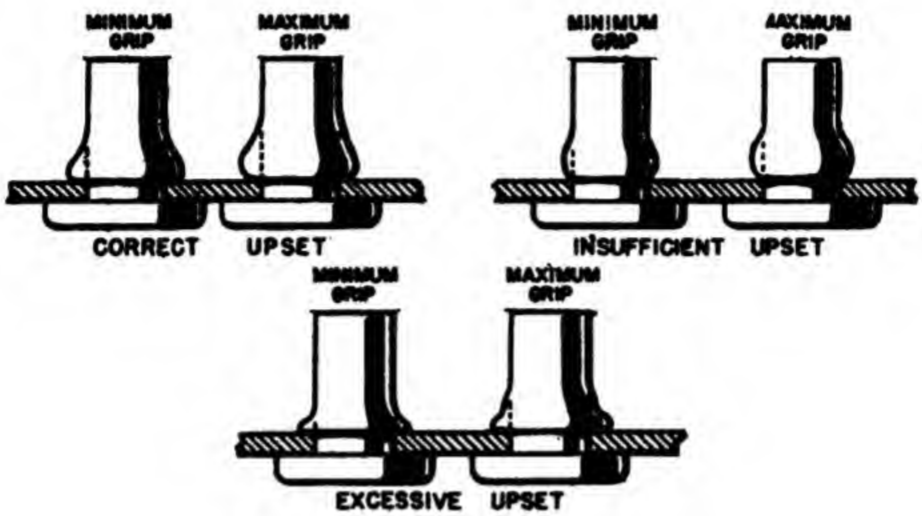


Figure 86.—Results of varying pressure.

Accessory Screws

The use of accessory screws is essential in rivnut installation. These devices are of two types—the attachment screw and the plug screw.

Attachment screws are used to fasten parts that are to be joined by means of rivnuts. Since open rivnuts will not withstand any great shear load, the plug screw assures added safety. Plug screws are also installed in rivnuts to keep salt water spray from getting into the interior of the airplane as well as to keep air out of sealed compartments.

Rivnut Installations

A special key seating tool, such as shown in figure 87, is used for notching the keyway in the sheet. Both pneumatic and hand-operated tools are used for installing rivnuts.

Hand tools such as that in figure 87 are available for straight heading and also for heading performed at angles of 45° and 90° to the head of the rivnut.

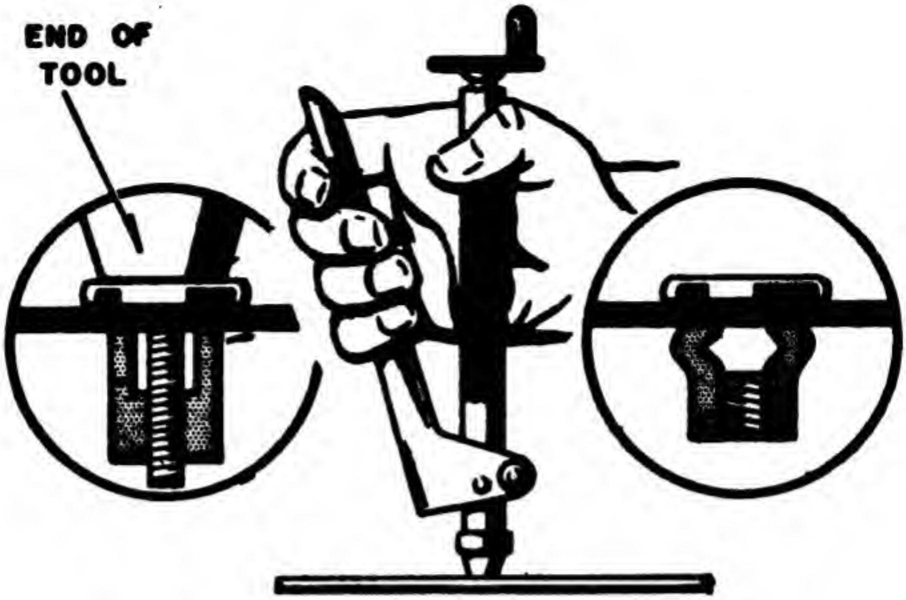


Figure 87.—Hand-operated tool for rivnut installation.

Drilling the hole for a rivnut requires as much precision as the hole for regular rivets, as the shank of the rivnut must fit snugly in the hole. In order to obtain a smooth round hole, it is desirable to make a lead hole before drilling to finished size. Chart 13 furnishes information regarding the relation in size between the lead hole and finished hole.

Size rivnut	Lead drill	Body drill
No. 6–32	No. 19 (0. 166")	No. 12 (0.189").
No. 8–32	No. 8 (0.199")	No. 2 (0.221").
No. 10–32	No. 1 (0.228")	¼" (0.250").

Chart 13.—Relation between size of rivnut, lead drill, and body drill.

When using the hand tool shown in figure 87, the rivnut must be hand threaded on the mandrel until its head rests against the anvil of the heading tool. It is important that the mandrel (screw) be at a 90° angle to the surface of the metal at all times. Unless both of these points are observed, the rivnut may be easily bent or broken.

Another type of aircraft fastener for blind spots is the lok-rivet and lok-skru (sometimes called Dillnuts). The lok-rivet is not tapped for a screw, whereas the lok-skru is. These devices are used for the same purpose as rivnuts, the difference being that the rivnut is furnished in one piece and the lok-rivet and lok-skru in two pieces—one screwed into the other, as shown in figure 88.

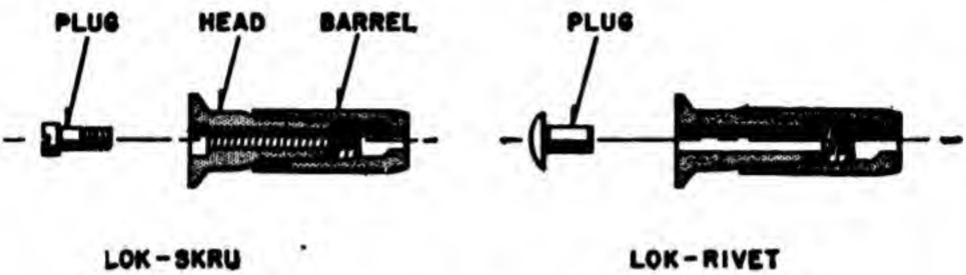


Figure 88.—Lok-skru and lok-rivets.

Since both lok-skrus and lok-rivets are similarly installed, the following description of the lok-rivet applies also to the lok-skru. The construction of the fastener and the method of installation is such that, when these fasteners are used as nut plates, manipulation of the key and slot required for the rivnut is unnecesary. Figure 89 illustrates the special tool used to install a lok-rivet.

Lok-Skru and Lok-Rivet Installation

The first step in installing lok-skrus and lok-rivets is to make certain that adequate clearance exists for the lok-rivet on the underside of the sheet, since the lok-rivet is longer than the rivnut. Then drill the hole for this fastener to a snug, push-tight fit. Predrilling and reaming is recommended.

Insert the tool blade into the lok-rivet so that the tool blade and the driver are held in the slots of the lok-rivet. Hold the ratchet handle stationary and turn the barrel blade handle to the left until the sleeve or barrel has come up firmly against the sheet on the other side, as pictured in step 2.

The final tightening should be made by taking a quarter turn or less on the ratchet handle while the handle blade is held stationary. The head of the lok-rivet should then be drawn tightly into the sheet as shown in step 3.

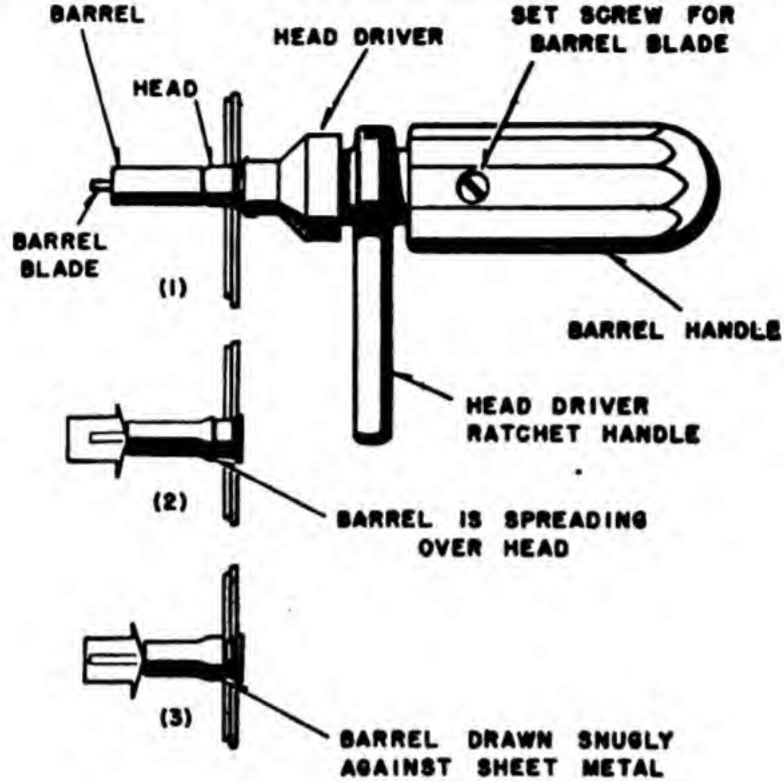


Figure 89.—Tools and steps for lok-rivet installation.

Finally, test the lok-rivet for tightness with a small screwdriver. Screws or plugs, attachments, and reinforcements may now be added.

SHAKEPROOF COWL FASTENERS

The Shakeproof cowl fastener, consisting of a main spring, stud, and cross pin, is becoming more and more popular. These devices are shown in figure 90.

Two special tools are required for installation of this fastener—pliers for assembling the cross pin in the predrilled stud, and a set of dimpling dies for countersinking the two sheets where flush heads are used. Shakeproof fasteners are supplied in the five head types illustrated in figure 90.

6-45	6-75	6-100	6-120	6-140	6-160
8-45	8-75	8-100	8-120	8-140	8-160
10-45	10-75	10-100	10-120	10-140	10-160
6B45	6B75	6B100	6B120	6B140	6B160
8B45	8B75	8B100	8B120	8B140	8B160
10B45	10B75	10B100	10B120	10B140	10B160
6K45	6K75	6K100	6K120	6K140	6K160
8K45	8K75	8K100	8K120	8K140	8K160
10K45	10K75	10K100	10K120	10K140	10K160
6KB45	6KB75	6KB100	6KB120	6KB140	6KB160
8KB45	8KB75	8KB100	8KB120	8KB140	8KB160
10KB45	10KB75	10KB100	10KB120	10KB140	10KB160

Chart 12.—Rivnut grip range.

The rivnut type numbers shown in chart 12 are readily understandable. The figure at the left indicates the size of machine screw thread, while the figure at the right denotes the maximum grip in thousandths of an inch. The minimum grip equals the maximum grip of the preceding size except for the first rivnut in a series, when the minimum grip equals its head thickness for countersunk types and equals 0.010 inch for flat-head types.

The dash or letters between the figures designates the following:

Dash (—)	open and keyless
B	closed and keyless
K	open end with key
KB	closed end with key

Figure 86 illustrates the approximate results to be expected when the same rivnut is used within its minimum and maximum grip, but with varying pressures on the header tool.

Uses of Rivnuts

Rivnuts are primarily used as fastening devices where it is difficult to use ordinary rivets. Rivnuts were designed principally as nut plates for the attachment of de-icer boots.

After threading the rivnut on the mandrel, it is positioned in the work and upset by slowly drawing the handles together until solid resistance is felt. Excessive pressure beyond this point is unnecessary.

If the rivnuts are reinforced with SAE 2330 machined screws, the joint will have three to four times greater shear strength. It is desirable to fill the rivnut with plug screws even when no part is attached, as it increases the strength and prevents wind whistle. The plug screws will also prevent the entrance of moisture into the plate part.

Selection of Rivnuts

Flat-head rivnut lengths in 10–32, 8–32, and 6–32 sizes are chosen according to the following thickness range of the metal in use and the corresponding marks on the head of the rivnut.

Thickness range (inch)	*Identifying mark*
0.010–0.045	Blank
.046– .075	1 Mark
.076– .100	2 Marks
.101– .120	3 Marks
.121– .140	4 Marks
.141– .160	5 Marks
.161– .180	6 Marks
.181– .200	7 Marks
.201– .220	8 Marks
.221– .240	9 Marks

Countersunk rivnut lengths of the 100° variety, in 10–32, 8–32, and 6–32 sizes are selected in the same manner.

GRIP

Thickness range (inch)	*Identifying mark*
0.050–0.089	Blank
.090– .124	1 Mark
.125– .154	2 Marks

.155– .179	3 Marks
.180– .199	4 Marks
.200– .219	5 Marks

Countersunk rivnuts of the 115° variety come in the following grip ranges.

10–32 RIVNUT GRIP (115°)

Thickness range (inch)	*Identifying mark*
0.105–0.139	Blank
.140– .169	1 Mark
.170– .194	2 Marks
.195– .214	3 Marks
.215– .234	4 Marks
.235– .254	5 Marks

8–32 RIVNUT GRIP (115°)

Thickness range (inch)	*Identifying mark*
0.075–0.104	Blank
.105– .139	1 Mark
.140– .169	2 Marks
.170– .194	3 Marks
.195– .214	4 Marks
.215– .234	5 Marks

6–32 RIVNUT GRIP (115°)

Thickness range (inch)	*Identifying mark*
0.065–0.104	Blank
.105– .139	1 Mark
.140– .169	2 Marks
.170– .194	3 Marks
.195– .214	4 Marks
.215– .234	5 Marks

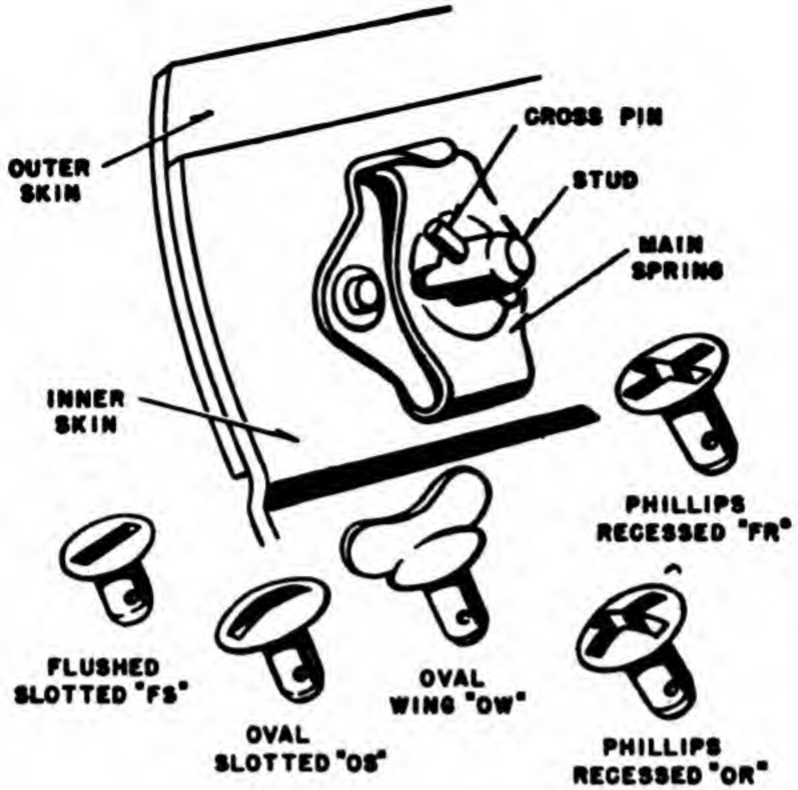


Figure 90.—Shakeproof fasteners.

Shakeproof fasteners are manufactured in two standard classifications—the No. 5, made to withstand tension up to 500 pounds, and the No. 7, which withstands tension up to 700 pounds.

The key to shakeproof fastener assemblies may be explained by using a symbol such as SP–FS–5–6– as an example. In this instance, the SP denotes Shakeproof fastener, and the FS means that the fastener has a flush slotted head. Other letter combinations designating head styles are as follows:

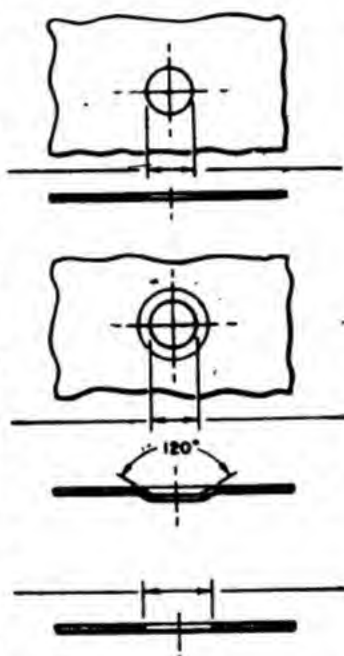
FR—Flush recessed head
OS—Oval slotted head
OR—Oval recessed head
OW—Oval wing head

The 5 indicates the Army-Navy strength classification of 500 pounds. If this third number were a 7, it would stand for the 700-pound classification.

The 6 in the above sample indicates the total sheet thickness which the Shakeproof Fastener will take—in this case, 0.055 to 0.064 inch. The last figure in the symbol represents maximum sheet thickness. The minimum sheet thickness is always 0.010 inch less. Standard range of sheet thickness for these fasteners is from 0.040 to 0.250 inch. The last zero is always omitted in the symbol.

Figure 91 illustrates Shakeproof fastener installation methods.

1. Locating from suitable mark or pilot hole, drill or punch clearance hole in inner sheet.



For Oval Head Type

Provide
.500
.516 Diameter Hole

For Flush Head Type

Provide
.500
.516 Diameter Hole

Dimple with Shakeproof 120° dimpling tool where inner sheet does not exceed .050, unless nested dimples of inner and outer sheets cause interference in main spring mounting.

.705 Minimum Dia.
.720 Maximum Dia.

Where outer dimpled sheet exceeds .050 provide undimpled clearance hole in inner sheet.

For Oval Head Type

Provide
.562
.578 Diameter Hole

For Flush Head Type

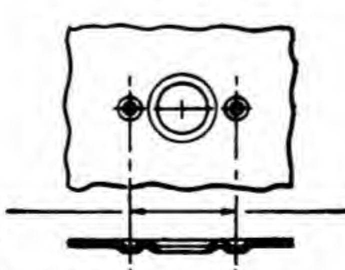
Provide
.562
.578 Diameter Hole

Dimple with Shakeproof 120° dimpling tool where inner sheet does not exceed .060, unless nested dimples of inner and outer sheets cause interference in main spring mounting.

.795 Minimum Dia.
.810 Maximum Dia.

Where outer dimpled sheet exceeds .060 provide undimpled clearance hole in inner sheet.

2. Drill or punch 2 holes and dimple for 1/8 — 100° countersunk rivets (AN426-4).



1" Centers

Machine countersink rivet holes if inner sheet thickness exceeds .030.

1⅛" Centers

Machine countersink rivet holes if inner sheet thickness exceeds .060.

3. Rivet Main Spring in place.

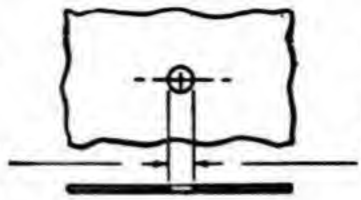
4. Locating from suitable mark or pilot hole, drill or punch clearance hole in outer sheet.

For Oval Head Stud

.261 Minimum Diameter Hole

For Extra "Float"

Up to .312 Maximum Diameter Hole



For Oval Head Stud

.328 Minimum Diameter Hole

For Extra "Float"

Up to .404 Maximum Diameter Hole

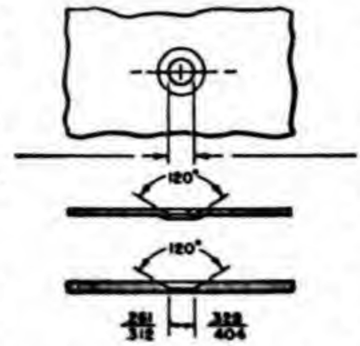
For Flush Head Stud

.261 / .266 Diameter Hole

Dimple with Shakeproof 120° dimpling tools for thicknesses not exceeding .100.

or

Machine Countersink when outer sheet thickness exceeds .100".



For Flush Head Stud

.328 / .332 Diameter Hole

Dimple with Shakeproof 120° dimpling tools for thicknesses not exceeding .100.

or

Machine Countersink when outer sheet thickness exceeds 100".

NOTE: In special applications (plywood, etc.) or where adaptions are to be made to existing tooling, grommets may be supplied.

5. With stud in installed position (through outer sheet) finger insert cross pin in hole in stud shank.

6. Press fit cross pin in stud with special Shakeproof pliers.

6a. If it is desired to remove or exchange stud, then cross pin may be removed with special plier jaw attachment. In this operation, effort is reduced by slightly opening the plier jaws with the toggle screw.

Figure 91.—Shakeproof fastener installation instructions.

CAMLOC FASTENERS

Camloc fasteners are used to secure cowl panels and access doors which must be opened frequently. Typical uses of this device are shown in figure 92.

These fasteners are flush mounted, very light in weight, require but a quarter turn to lock or unlock, and are adaptable to both straight or curved sheets of metal, plastic, or plywood.

Camloc fasteners are furnished in two sizes—the large size, with a ⅜-inch diameter stud head. The large size consists of three parts—stud assembly, grommet, and cam collar—

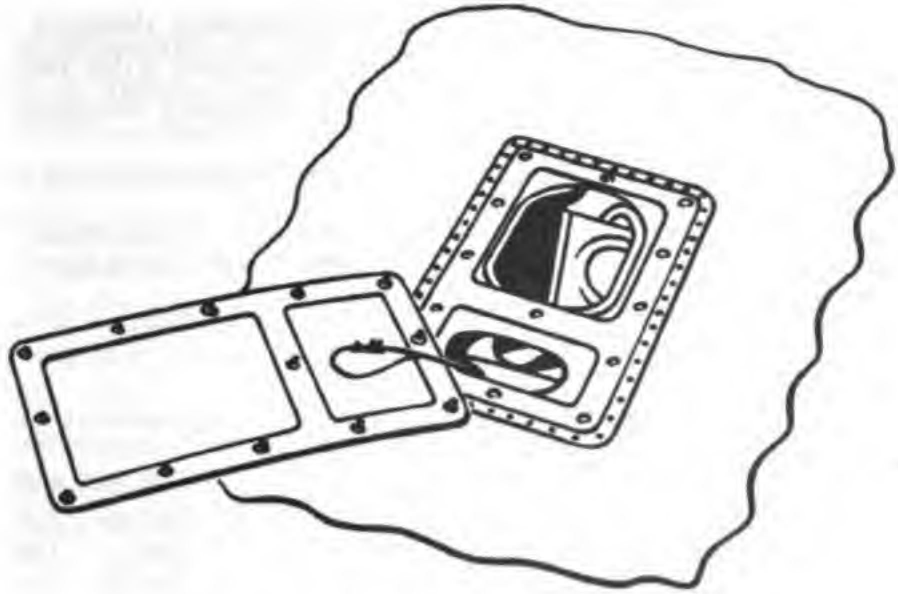


Figure 92.—Use of Camloc fasteners.

while the small size has only two parts—the stud assembly (which combines the stud and grommet) and the cam collar. These parts are pictured in figure 93.

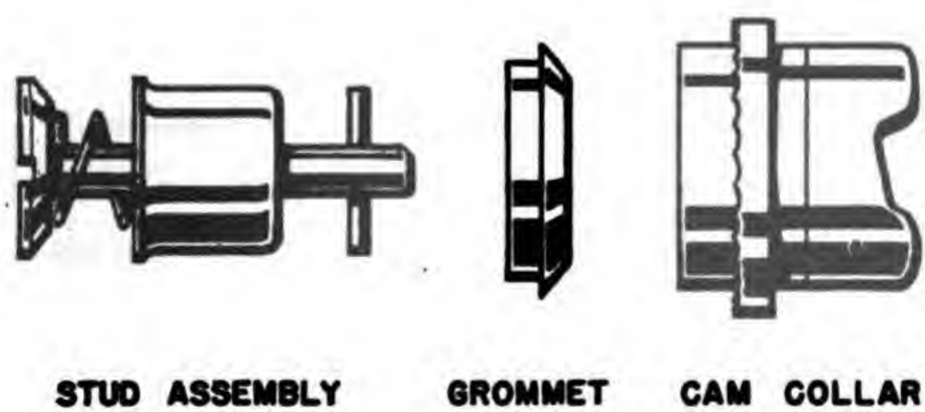


Figure 93.—Camloc parts.

The stud assembly is the operating part of the fastener, and serves to lock the panel to the structure. It consists of stud, cross pin, spring, and spring cup permanently assembled at the factory, and is so designed that it can be quickly inserted into or removed from the grommet as a unit.

The grommet is the steel ring permanently flanged into a hole in the removable panel. It is furnished with various skirt lengths for use in materials of different thicknesses.

Name of part	Manufacturer's part No.	Outer sheet thickness	Total sheet thickness
*Collar [1]	2002–502		
Stud	2500A–1	0.040 to 0.049	0.070 to 0.090
Stud	2500A–2	.040 to .049	.100 to .129
Stud	2500A–3	.040 to .049	.130 to .159
Stud	2500A–4	.040 to .049	.160 to .189
Stud	2500A–5	.040 to .049	.190 to .219
Stud	2500A–6	.040 to .049	.220 to .249
Stud	2500C–1	.060 to .069	.070 to .099
Stud	2500C–2	.060 to .069	.100 to .129
Stud	2500C–3	.060 to .069	.130 to .159

*Where inner sheet thickness exceeds 0.064, this collar may still be used if sheet is countersunk or counterbored.

Large-size Camloc (⅜-inch diameter stud head).

Name of part	Manufacturer 4002, dash No.	Sheet thickness
Collar	–504	(Inner) 0.050 to 0.070
Collar	–524	(Inner) .050 to .070
Grommet	–B	(Outer) .025 to .031
Grommet	–C	(Outer) .032 to .048
Stud	–1	(Total) .051 to .080
Stud	–2	(Total) .081 to .110
Stud	–3	(Total) .111 to .140
Stud	–4	(Total) .141 to .170
Stud	–5	(Total) .171 to .200
Stud	–6	(Total) .201 to .230
Stud	–7	(Total) .231 to .260

Small-size Camloc (³⁄₁₆-inch diameter stud head).

Chart 14.—Camloc selection chart.

The grommet is omitted from the design of the smaller type of fastener, where the stud assembly is flanged directly into the removable panel.

The cam collar is a forged aluminum receptacle with a stainless steel cap to protect the wearing surfaces. It is permanently attached to the aircraft structure that has been either dimpled or countersunk so that the cam collar does not extend above the mounting surface. The cam collar is made with various skirt lengths for flanging into different thicknesses of material. Each length has its own specification number.

Insertion of the stud assembly is a simple operation, consisting merely of compressing the spring of the stud assembly with pliers and pushing the stud through the grommet. Camloc pliers No. 4–P are convenient for this job.

Selection of the Proper Size Fastener

Select the grommet and collar according to the thickness of the sheet in which they are to be installed. The stud is selected according to the total thickness of sheets to be fastened, including the thicknesses of any "air spaces" formed by dimpling the sheets around the hole.

Chart 14 may be used as guides in selecting the proper size fasteners to use.

QUIZ

1. In what sizes can you obtain Cleco fasteners? How are the various sizes identified?
2. What type PK screw would you use to join sheets 0.060 inch in thickness?
3. If you were fastening a part that would be removed frequently, and replaced frequently, what type fastener would you use?
4. What shape head would you find on a type A Duzus fastener?
5. What type fastener would you use for the nut plates for attachment of de-icer boots?
6. What type fastener would be indicated by the symbol SP–FS–5–6?

CHAPTER 7

GENERAL STRUCTURAL REPAIR

Each aircraft structural member has been designed to perform a specific function or to serve a definite purpose. In the repair of aircraft, the prime objective is to restore the injured or damaged part to its original condition. Very often, replacement is the only way in which this can be effectively done. When repair of a damaged part is possible, however, the first step in such procedure is for the Aviation Structural Mechanic to carefully study the part in order to fully understand its purpose or function.

Strength, for instance, is the principal requirement in the repair of certain structures, while in other structures entirely different characteristics may be desired. For example, fuel tanks, seaplane floats, and hulls must be pro-

tected against leakage, but cowlings, fairings, and similar parts require totally different properties—neat appearance, streamlined shape, and accessibility.

Therefore, the functions of any damaged part must be carefully determined. The next step is the planning of the best way to restore that part to its original efficiency. Competent and satisfactory repair will then follow as a natural consequence.

SKIN REPAIR

Damages may occur in either of two types of skin—"closed" or "open." "Closed" skin is that which is accessible from one side only, and repairs to this type of damage challenge the ingenuity of the mechanic if the original strength is to be restored. "Open" skin is a metal surface which is accessible for repair from either side, and damages in this type of skin present few difficulties.

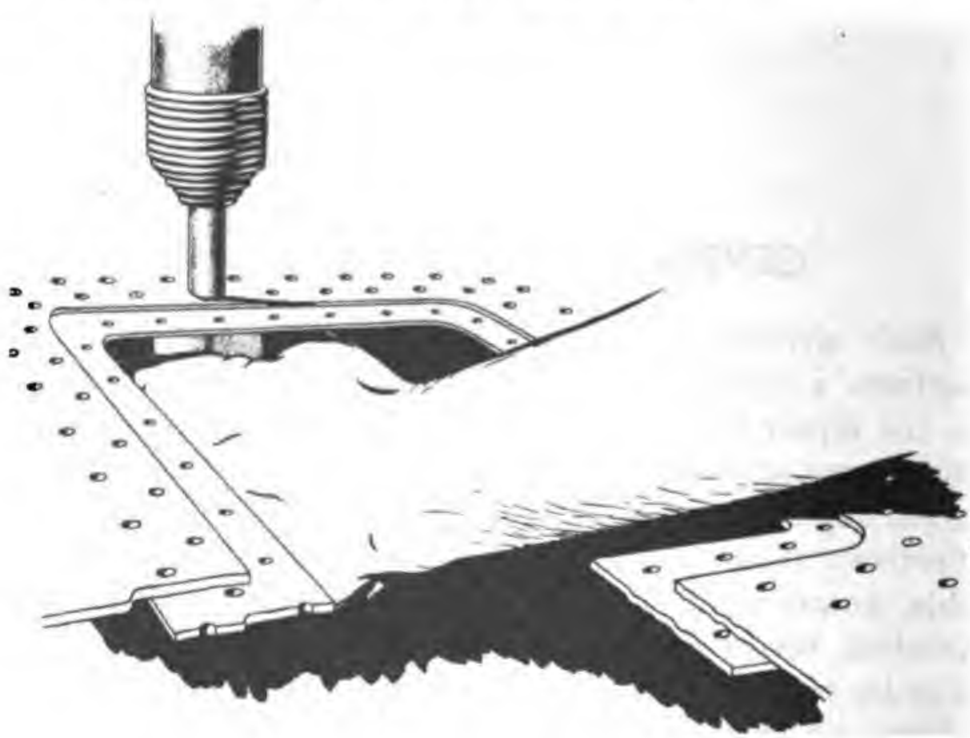


Figure 94.—Joining backup ring to skin.

Both "open" and "closed" skin may be repaired with either a lap or flush patch. Since "open" skin is accessible from both sides, it may be repaired in the conventional manner. When "closed" skin damage is repaired with a lap patch, some type of blind fastener—such as explosive rivets or cherry rivets—must be used to fasten the patch material in place. Flush patches in "closed" skin permit the use of solid aluminum alloy rivets for fastening the backup ring, and some type of blind fastener or machine screws for holding door or cover in place on the ring and flush with the surface of the original skin. If solid rivets are used to join the backup ring to the skin, the ring must have a hole in the center sufficiently large to permit use of a buckling bar, as shown in figure 94.

The backup ring may be attached to the under side of "closed" skin in one of two ways. The repair may be made elliptical with its major axis (length) great enough to permit the backup ring to be slipped in the hole in the skin. If the repair is not made in an elliptical shape, the ring may be split to allow its insertion into the hole in the skin.

When machine screws are used to fasten the door of cover in place in a flush-type repair, provisions must be made for the threads on the screw. Either a nut plate or anchor nuts may be used to fasten a cover with machine screws. If a nut plate is used, the backup ring is made of a gage which is heavy enough to provide tapping surface for at least three threads of the machine screw. If anchor nuts are used, the backup ring may be the same or one gage heavier than the original skin and the anchor nuts are riveted to the ring before it is fastened to the skin.

PATCHES AND PATCHING

Repairs to the metal skin of an airplane, whether it be of the "open" or "closed" type, require that the patch material be the same gage or one gage heavier than the original skin. Naturally, the material used must equal the original skin in temper and type. The amount which a lap patch or backup ring will extend beyond the removed area of the skin is

determined in every case by the number of rows, spacing, and size of rivets which are to be used to fasten the patch in place. The size of the patch in the case of a lap patch is determined by adding the following parts of a patch:

A (damaged area removed), plus twice B, C, and D (rivet edge distance and spacing).

CHAMFER AND CRIMP LAP PATCHES should have their edges chamferred and crimped. Treating the edges of the patch in this manner makes a tight-fitting repair, especially for watertight areas. The edge should be chamferred to ½ the metal thickness and then crimped to approximately 15°. A chamfer is made with a file, and the crimping is done with a crimping machine or a mallet on a stake, as demonstrated in figure 95. In this illustration, (A) shows the assembled patch, while (B) and (C) indicate the manner in which beveling and crimping are done.

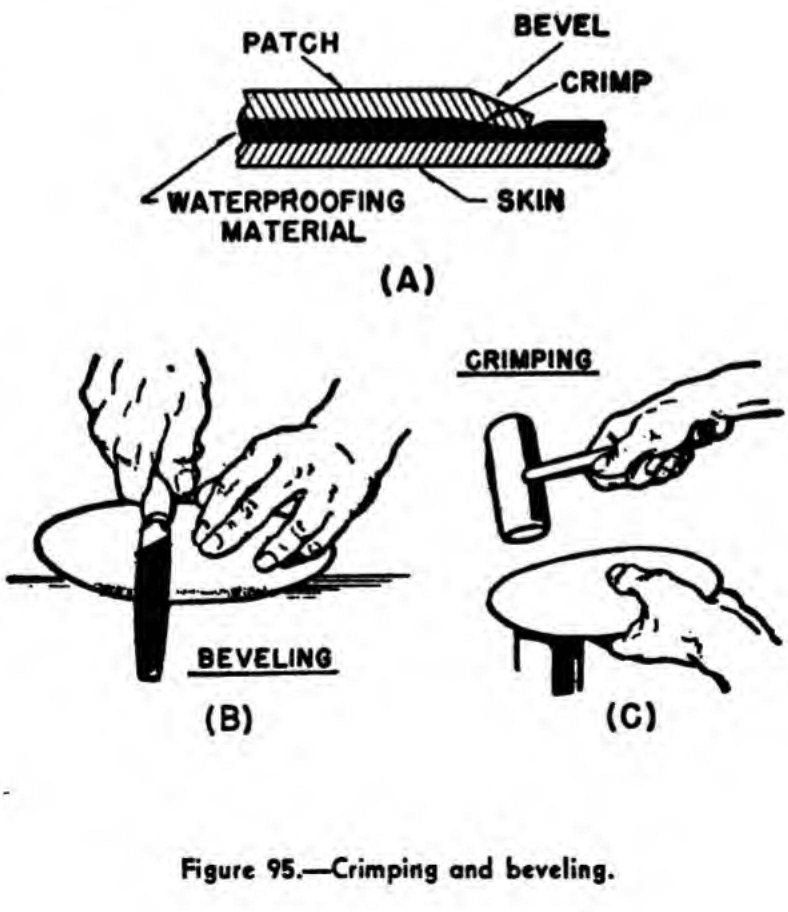


Figure 95.—Crimping and beveling.

Before any patches are assembled and riveted in place, all burrs must be removed from all drilled holes, and all edges on both the patch and the original skin. If the removed area is shaped so that it has corners, they should be rounded with a generous radius and the corners of the patch rounded to match them.

Waterproofing

Skin repairs to floats and hulls often require that the repair be watertight. Seals, floats, and hulls should be sealed and filleted in such a manner as to definitely preclude all possibility of moisture entering any part of the seam. A preferred method for use above a line one inch above the full load water line is the application of a plastic organic compound such as zinc chromate paste. Neoprene cement may also be used for floats and hulls. Below the water line defined above, and for other watertight seams, soya bean impregnated fabric, zinc chromated tape, and other similar materials should be used.

MAKING A LAP WATERTIGHT PATCH

Let us suppose that the damage to be repaired is confined to a small area and located in an easily accessible spot.

The first step in the repair procedure is the cleaning up of the tear or hole by removing or bumping out all dents and irregularities.

The damaged area is then symmetrically trimmed out so that no weakened metal or sharp corners exist. Remove the paint from the trimmed hole for a distance back from the edge of at least ¾ inch, and smooth the edges of the hole with a file.

Select patching material of the same alloy and either the same or greater thickness as that of the skin being repaired, preferably greater. Scribe the outline of the hole upon the patch material. If the surface of the skin has a contour, the patch should conform to it. If the patch is not formed to match the contour of the skin, the finished repair has a tendency to "oilcan," especially if the patch material is of a thicker gage than the original skin.

The amount which the patch should overlap the edges of the hole depends upon the size of the opening being repaired, since room must be allowed for rivets. As a general rule, for a hole approximately 1½ to 2 inches, a patch having a single row of rivets is sufficient. If a patch is small, the amount of overlap can easily be determined by figuring the proper edge distance for the rivets. Thus, if the hole is 2 inches, the patch should overlap approximately ½ inch if ⅛-inch diameter rivets are used. This provides a two-diameter edge distance on either side of the row of rivets, as shown in figure 96.

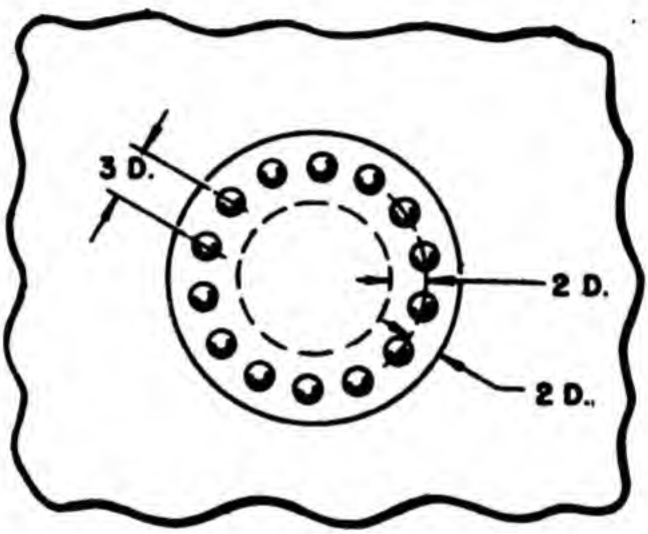


Figure 96.—Amount of overlap for one row of rivets.

The same rule can be followed in figuring the correct overlap for a double row of rivets. For instance, on a patch covering a 4-inch hole, the overlap should be about one inch. Assuming that ⅛-inch rivets are used, this provides an allowance of two-rivet diameters on either side of the double row of rivets, plus a space of four-rivet diameters between the rows. Figure 97 illustrates these proportions.

When the rivet holes have been drilled in the patch, place the patch over the opening and drill two or three matching rivet holes in the skin. Then insert Cleco fasteners or sheet metal screws to hold the patch temporarily in place. Then

drill the remaining holes, take off the patch, and eliminate all the burrs.

The next step is to prepare the waterproofing material. Cut a section which will extend slightly beyond the edge of the patch, impregnate it with sealing compound, place it over the hole, and fit the patch into place. Insert machine screws in every third or fourth rivet hole. Use nuts on the machine screws, drawing the patch tight enough so that sealing compound is squeezed out around the entire patch.

Now drive rivets in the open holes, then replace the metal screws with rivets. Finally, clean up the entire patch by

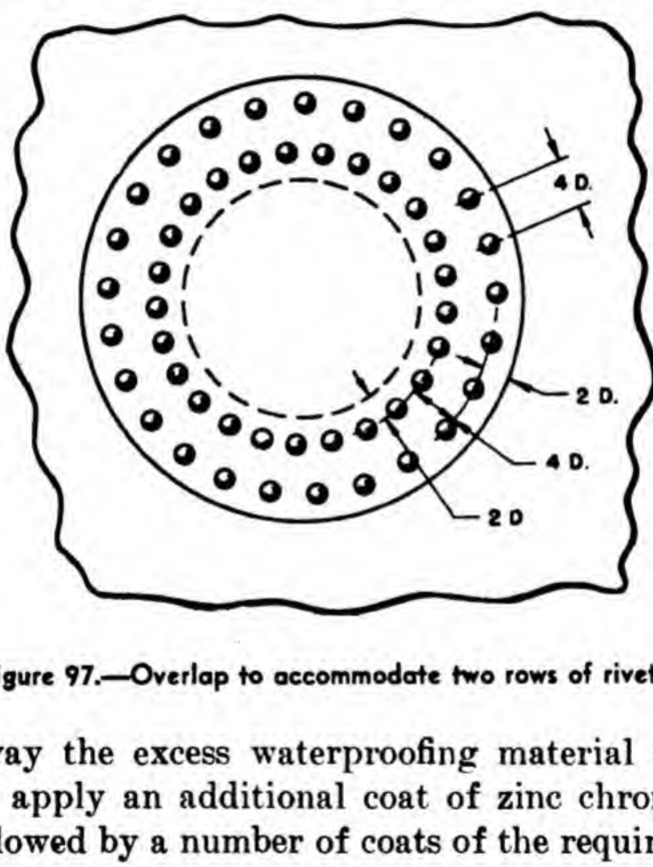


Figure 97.—Overlap to accommodate two rows of rivets.

cutting away the excess waterproofing material from the edges, and apply an additional coat of zinc chromate and primer followed by a number of coats of the required finish.

SKIN REPAIR

As we discussed in the opening phase of our study, modern aircraft construction utilizes the monocoque and semi-monocoque fuselages. As will be recalled, in the monocoque fuselage there are no longitudinal (lengthwise) members. Reinforcing rings or bulkheads are used at regular inter-

vals to provide sufficient rigidity to maintain the proper contour.

Semimonocoque construction is similar to the monocoque with the addition of longitudinal members known as stringers. On both types, the outer covering, called SKIN, carries high stresses, from whence the term "stressed skin" originated. Since this outer covering must withstand a great deal of stress, it can readily be seen that repair to any part of it must be carefully made so that the damaged section will continue to carry its share of the load.

Skin repairs are divided into two classes—the stressed and the nonstressed type. Nonstressed repairs are made on engine cowlings, fairlings, and other parts that merely serve as streamlining for the various structural parts of an airplane. Since these parts are not intended to carry any load, they are made from non-heat-treatable alloys—2S, 3S, and 52S.

Other parts of the skin of a metal aircraft are subjected to high stresses, consequently the repair material must equal the original strength. For this purpose the heat-treatable alloys, 17S–T and 24S–T, are used.

STRENGTH OF REPAIRS

Where the loads to be carried are not known, all repaired parts must be at least as strong as the original area. The cross section of the patch reinforcement or splice must at least restore the initial strength to the damaged part.

In members subject to compression or bending, it is advisable to have the splice on the outside of the repaired member in order to obtain a greater bending strength. When this is impossible, the next heavier gage material should be used.

Abrupt changes in cross section are to be avoided in order to eliminate dangerous stress concentration. This can be accomplished by making small patches round or diamond shaped instead of rectangular. For the same reason, sharp corners are to be avoided, and all holes should have generous radii.

Monocoque structural material at the present time consists almost entirely of aluminum alloy. High strength rolled sheet is used for the skin; formed sheet for bulkheads and ribs, and extrusions or formed angles for stringers. The material for all replacements or reinforcements should be chosen on the same basis as the material of the airplane being repaired. Chart 15 lists the various alloys and methods used in aircraft construction. If it is necessary to substitute a weaker alloy than the original, a heavier gage must be used to give the equivalent cross-section strength. On the other hand, never use a smaller cross section even when using a

Commercial designation	Navy specification	Army or Navy tensile strength p. s. i.	Allowable bearing p. s. i.	Remarks
2S½H	47A2½H	N 16,000		Do not use—replace with 3S½H.
3S½H	47A4½H	AN 19,500		Welded tanks.
4SO	47A9 Temp. A.	AN 29,000 Max.		Spun parts.
17S	47A3	AN 55,000	75,000	Do not use—replace with 24S.
Alclad 17S	47A6	AN 50,000	68,000	
24SO	47A10 Cond. A (annealed).	AN 35,000 max.		Formed structural parts, ribs, bulkheads, etc.; must be heat-treated to 24ST after forming.
24ST	47A10 Cond. I (H. T.).	AN 62,000	90,000	Skin and parts bent not formed.
24SRT	47A10 Cond. T. R. (H. T. & R.).	AN 65,000		Highly stressed flat skin or web.
Alclad		AN 32,000		Same uses as 24S above. Better resistance to corrosion; lower strength.
Alclad 24ST	47A8 Cond. T (H. T.).	AN 56,000	82,000	
Alclad	47A8 Cond. T. R. (H. T. & R.).	AN 58,000		
52SO	47A11 Temp. A.	AN 31,000		Formed nonstructural parts. Cowling and fairings.
52S¼H	47A11 Temp. ¼H.	AN 31,000		

Chart 15.—Tensile strength of aluminum alloy sheet.

stronger metal. No material should be substituted for Alclad unless special precautions have been taken to prevent corrosion.

REPAIR OF SMALL CRACKS IN NON-STRESSED SKIN

Drill a hole—$\frac{3}{32}$ or $\frac{1}{8}$ inch—at the end of the crack to prevent the crack from spreading.

Cut a section of reinforcing material of the same type and thickness as the original sheet so that it extends at least $\frac{3}{4}$ inch or 1 inch beyond all sides of the crack. The shape of this patch will depend upon the pattern and location of the crack. Patches are usually square, circular, rectangular, or diamond shaped, as shown in figure 98.

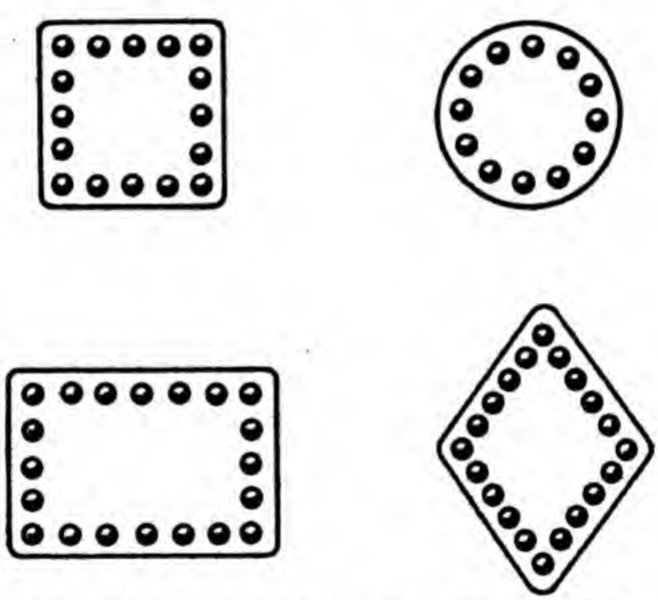


Figure 98.—Patches for repairing non-stressed skin.

When the patch has been cut to shape, round the corners and lay out the location for the rivet holes, then drill several holes in the patch plate to serve as guides for drilling the holes in the skin to be covered. Fasten the patch temporarily with sheet metal screws or Clecos, and drill the remaining holes. Remove the patch and clean off all burrs. Then apply a coat of zinc chromate primer to the under side of the patch and the surface of the skin. Replace the patch and rivet it in place.

REPAIR OF SMALL CRACKS IN STRESSED SKIN

The repair of cracks in stressed skin is practically the same as that for cracks in non-stressed skin, except that more rivets are used. The plate is attached with rivets spaced approximately ¾ inch apart in two rows staggered about ⅜ inch apart, as shown in figure 99.

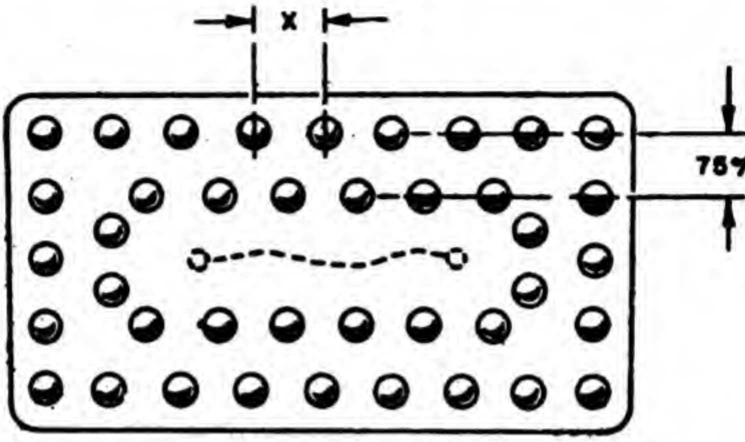


Figure 99.—Patch for repairing cracks in stressed skin.

REPAIR OF HOLES

Holes less than $^3/_{16}$ inch in diameter in stressed or non-stressed skin may be repaired by filling them with a rivet. Drill or file the hole until it is round, then plug it with a rivet of the proper size. Holes larger than $^3/_{16}$ inch and less than 1 inch in diameter are repaired by covering it with a lap patch as shown in figure 100.

Holes in stressed skin may be of the open or closed type. An open hole is one in which both sides of the damaged surface are accessible, and the closed is one which is not accessible from the inside. Patches for either type of hole may be of the lap or flush type. In either case, rivets with head shapes conforming to those originally used on the skin should be used.

Figure 101(A) shows the layout for a lap patch, while figure 101(B) illustrates the layout for a flush patch.

In patching an open hole, first cut away the sharp and ragged edges. Then cut the patch from material of the

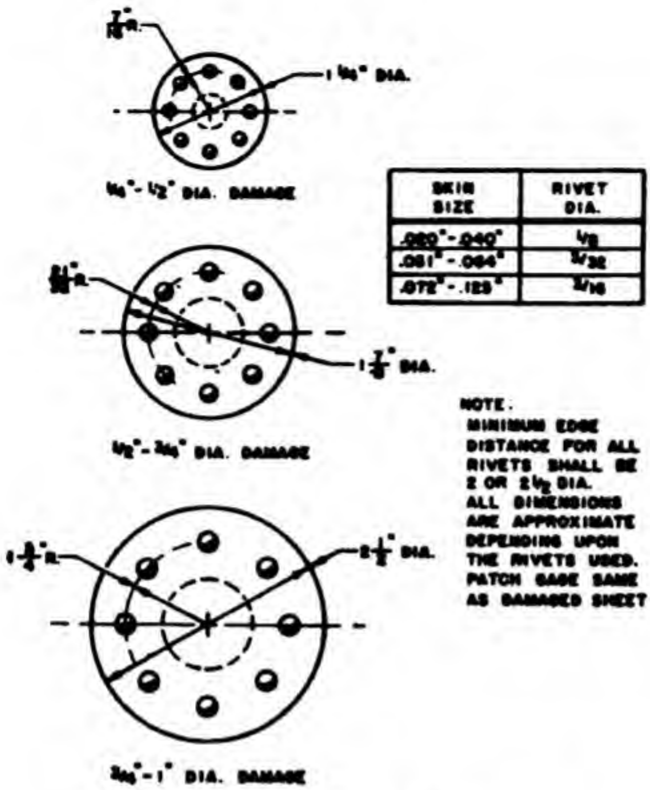


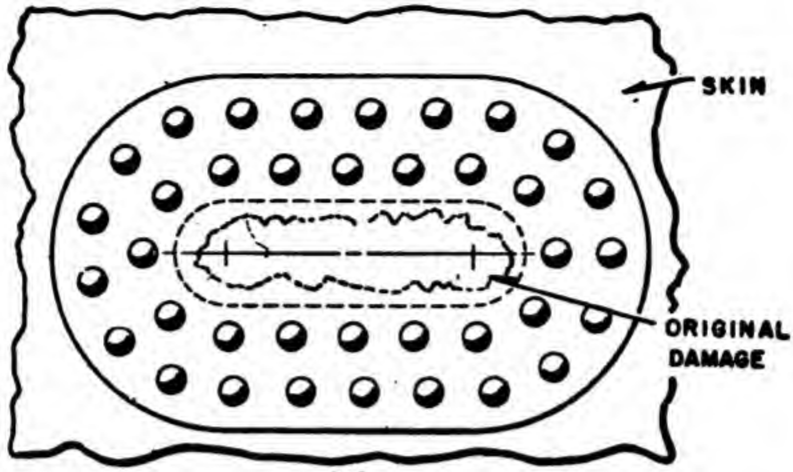
Figure 100.—Lap patch for a small hole.

same thickness as the skin panel or one gage heavier. If a flush patch is to be made, prepare the backup plate as described in the repair of watertight patches.

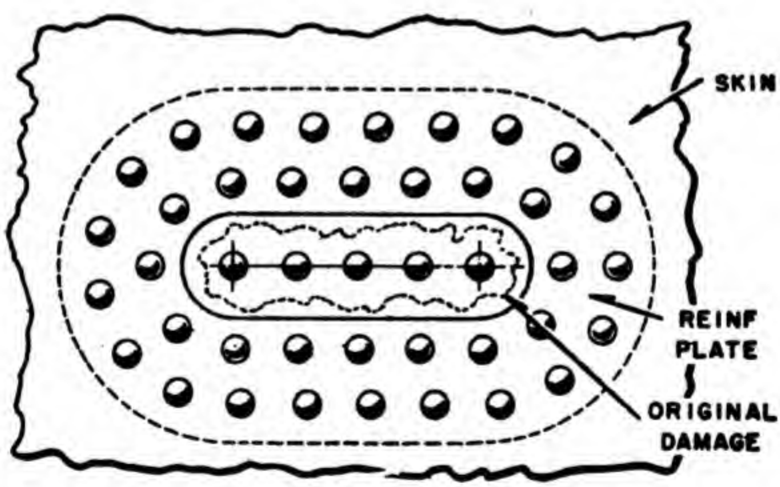
Layout the location of the rivet holes on the patch plate. To calculate the minimum number of rivets to be used, multiply the length of the hole by eight after the ragged edges have been cut away. The answer will be the minimum number of rivets required on each side of the break to attach the patch plate to the skin. For example, assume that the length of the hole is 2.5 inches:

$$8 \times 2.5 = 20$$

Therefore, a minimum of 20 rivets must be used on each side of the hole, or 40 rivets for the entire reinforcement.



(A)



(B)

Figure 101.—Lap and flush patches for an open hole.

This rule of multiplying the length of the hole by 8 will apply to most stressed skin patches. It is, in fact, a simplification of the involved rivet formula, which is as follows:

$$\frac{\text{cross-sectional area removed} \times \text{stress in skin}}{\text{allowable bearing strength of sheet or shear value of rivet}}$$

Assume that:

Opening=3″ (see fig. 160).
Skin thickness=0.032″ (Alclad 24S–T).
Cross section area=$3 \times 0.032 = 0.096$.
Skin stress=56,000 p. s. i.
Load=$0.096 \times 56{,}000 = 5376$ pounds.
Rivets used=$\frac{3}{32}$″ diameter A17S–T.
Bearing strength of sheet (24S–T Alclad) =245.

$\frac{5376}{254} = 22$ rivets (this number is required on each side of the reinforcement).

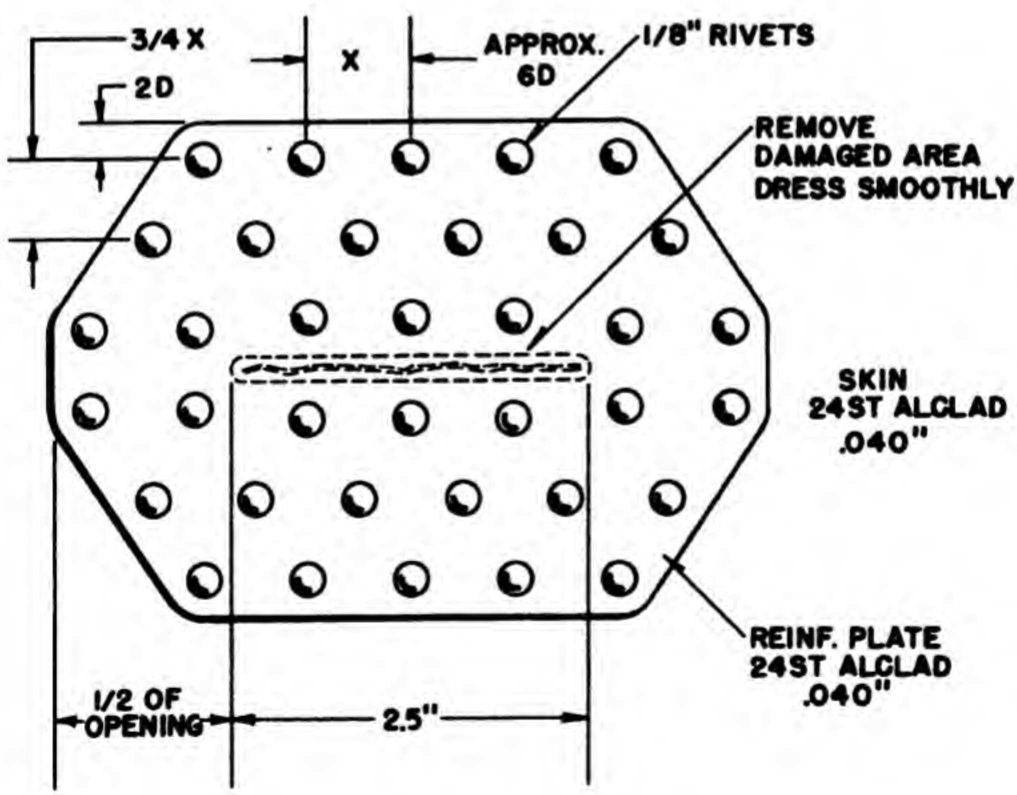


Figure 102.—Rivet spacing.

FLUSH TYPE ACCESS HOLE PATCH

This type of hole is most satisfactory for general use on an airplane. The hand hole is cut as shown in figure 103, and is reinforced with a backing plate, installed on the inside of the skin. This plate is usually one gage heavier than the skin itself.

Nut plates are riveted to the inside edge of this plate, which is fastened to the skin with rivets spaced approximately 1 inch apart in two staggered rows one-fourth inch minimum distance from the edge. The inspection door, which is cut to fit the hand hole in the skin, may be of the same gage as the skin material. It must be drilled to match the nut plates.

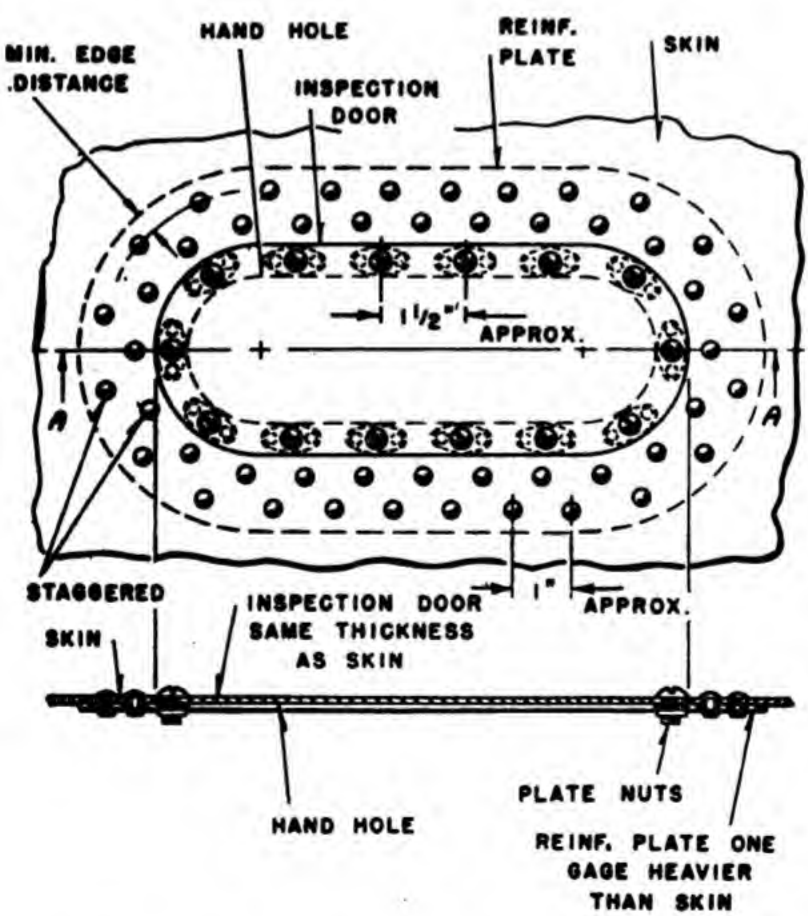


Figure 103.—Installation of a flush type access patch.

LAP TYPE ACCESS HOLE

As a substitute for the flush type hole, the lap type has proven most satisfactory. An example of the lap type is shown in figure 104. A circular hole is cut in the skin and reinforced on the inside with a ring ¾ inch wide. No. 10–32 nut plates and screws, spaced approximately 1½ inches apart, are riveted to the ring.

The ring, which must be split for insertion into the hole, is then riveted to the inside of the skin with two rivets between each nut plate. The cover plate is drilled to match the nut plates.

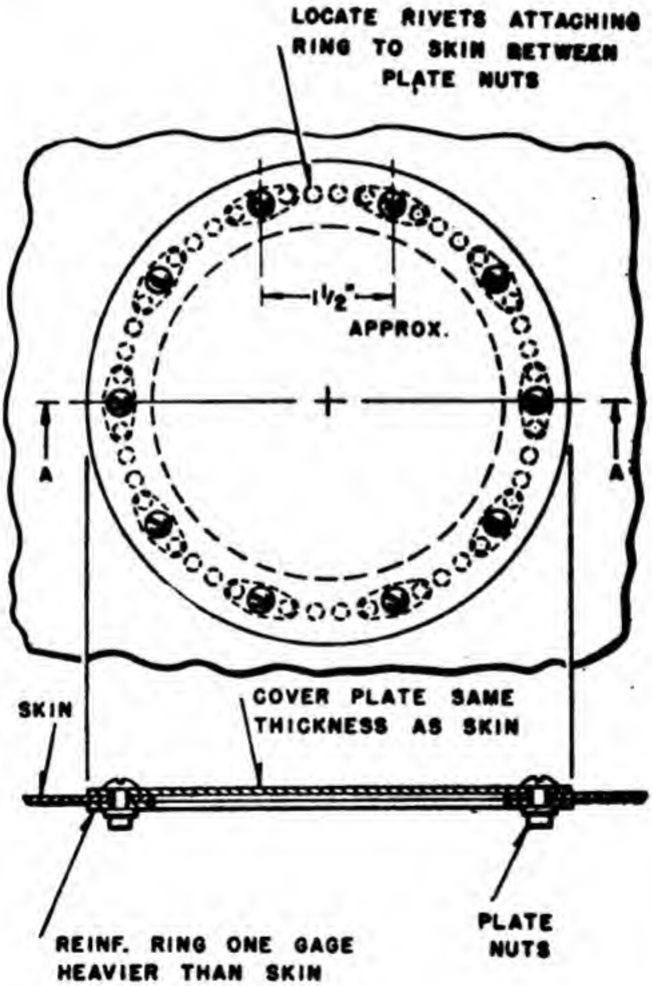


Figure 104.—Lap type access patch.

Extruded or formed angle splices are used to repair stringers, stiffeners, and other structural parts of an aircraft.

Stringers, in a semimonocoque structure, are employed throughout the parts of the plane as longitudinal structural members to connect the bulkhead rings or ribs, and to distribute stresses. Stringers are used in the wings, fuselage, landing gear, fins, rudders, stabilizers, elevators, engine nacelles, and cowling of an airplane. Figure 105 illustrates these units.

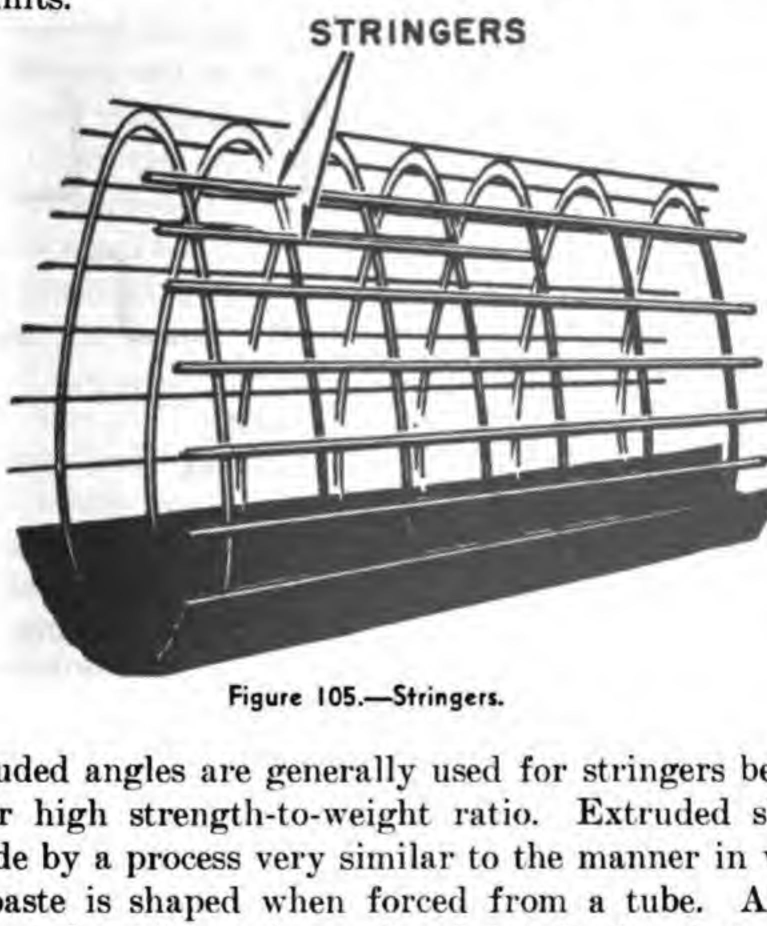


Figure 105.—Stringers.

Extruded angles are generally used for stringers because of their high strength-to-weight ratio. Extruded shapes are made by a process very similar to the manner in which tooth paste is shaped when forced from a tube. An extruded angle stringer is produced by forcing hot metal through a die in which there is an opening which corresponds to the desired cross section of a stringer. This process frequently provides more efficient utilization of the metal than do rolled shapes. Since they require high strength, extruded angle stringers are made from 24S–T alloy. Figure 106 shows various shapes of extruded angle stringers.

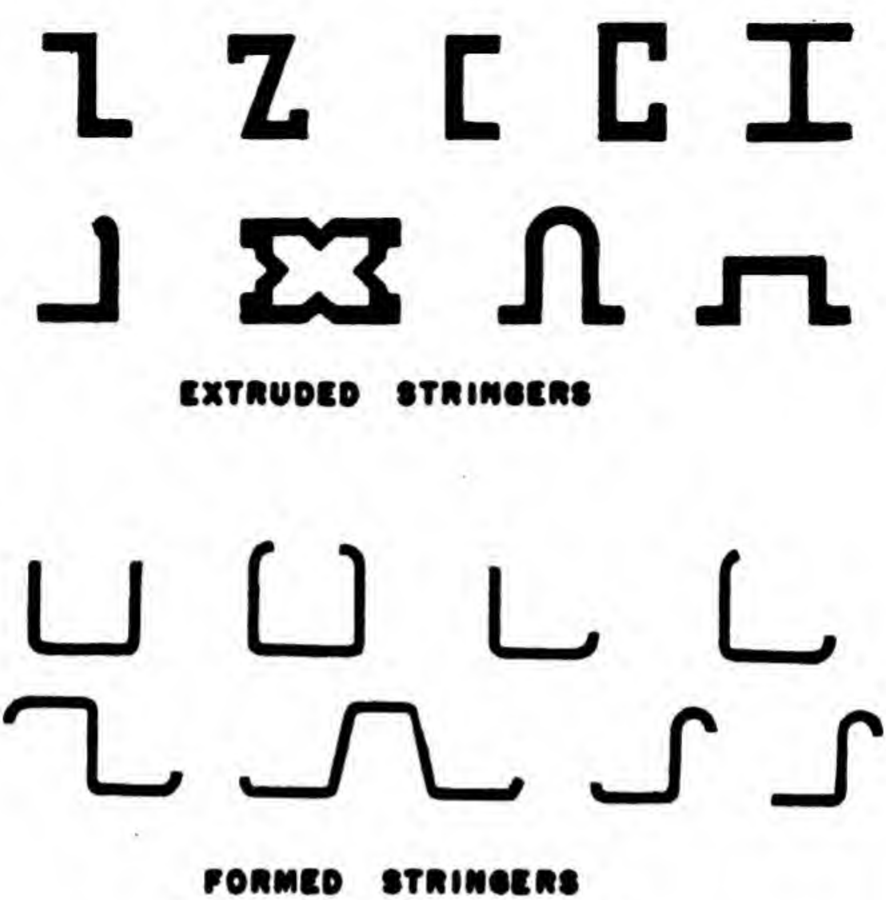


Figure 106.—Types of stringers.

Stringers, however, are not always made of extruded angles. They may be made of numerous types and shapes formed on breaks or various combinations of die presses. They are made from annealed aluminum alloy which is heat-treated after forming in order to maintain the maximum strength of the stringers. These are shown also in figure 106.

Splicing Precautions

Stringer repairs compare favorably with the repair of spars, bulkheads, ribs, etc., in that the number of rivets is determined in the same manner. The layout of the stringer repair differs, however, because of the cross-sectional shape and the loads imposed upon the stringers. For this reason, the following precautions are listed for consideration when repairing stringers.

1. In order to avoid eccentric loading and resultant buckling in compression, the splicing or reinforcing members should be placed as symmetrically about the centerline of the part being repaired as possible. There should be sufficient splice plates to prevent bending in any direction.

2. To prevent reducing the strength of the stringer in tension, the rivets should be staggered as much as possible. Two rows are usually not possible on an extruded angle stringer, but by placing the rivet holes from ½ to 1D off center from one another, a staggered effect may be achieved.

3. To avoid having concentrated loads on the end rivets of a stringer splice which tends to cause a progressive popping of rivets from the ends toward the center, it is best to taper the ends of the splice. The taper should begin at the second rivet from the end of the reinforcement splice. This prevents the splice from being rigid, thereby permitting the repair to bend with the rest of the structure.

TYPES OF STRINGER DAMAGE

Damages which stringers may sustain may vary widely from that which might be termed negligible to that which is so extensive that the entire stringer or a portion of it must be cut out and replaced.

Stringers may fail because of vibration. They may be weakened by corrosion, or they may be twisted or torn because of collision. Generally, there are two types of stringer damage—negligible and major.

Negligible damage is any smooth isolated dent (not more than $\frac{1}{16}$ inch in depth) which is free from cracks, abrasions, and sharp corners. Such dents may be filed smooth.

Any damage greater than that described as negligible is classed as major damage, and may take any of the forms pictured in figure 107 which illustrates (A) partial damage to one leg; (B) total damage to one leg, and (C) total damage to cross sectional area (both legs).

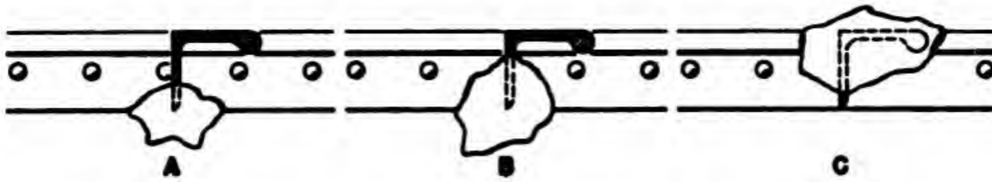


Figure 107.—Forms of major stringer damage.

Stringers are considered highly stressed members, whether they be in fuselage, wings, elevators, and so on. The location of a stringer determines the amount of stress to which it will be subjected. For most repair purposes, however, it is sufficient to know that stringers in the upper surfaces of fuselages and wings must be repaired to withstand 80 percent of the stress which might be imposed upon a fully stressed part (100-percent stress). This means that a stringer in the upper surface of a wing would require 20 percent less rivets for repair purposes than a stringer in the lower surface of a wing.

These rules are especially important in stringer repairs on the lower side of stresses skin wings where extremely high tension forces are encountered. When several adjacent stringers are spliced, the splices should always be staggered as much as possible, as figure 108. This will prevent the splices being directly opposite and insure the spread of stress concentration.

A FILLER SPLICE is a short section of the same shape as the original stringer, used to fill the space left when a damaged length of stringer is removed. A filler splice should never exceed 12 inches.

When removing the damaged stringer section, it is best to cut out the end in the center of two rivets so that the rivet continuity can be maintained in the repair. Cut the damaged part and file the ends smooth.

Cut out the filled, making it $\frac{1}{32}$ inch shorter in length than the length of the damaged section. This will allow a clearance of $\frac{1}{64}$ inch between each end of the replacement

and the original stringer, thus eliminating any possibility of stress developing from contact between the two parts. Figure 109 shows this clearance.

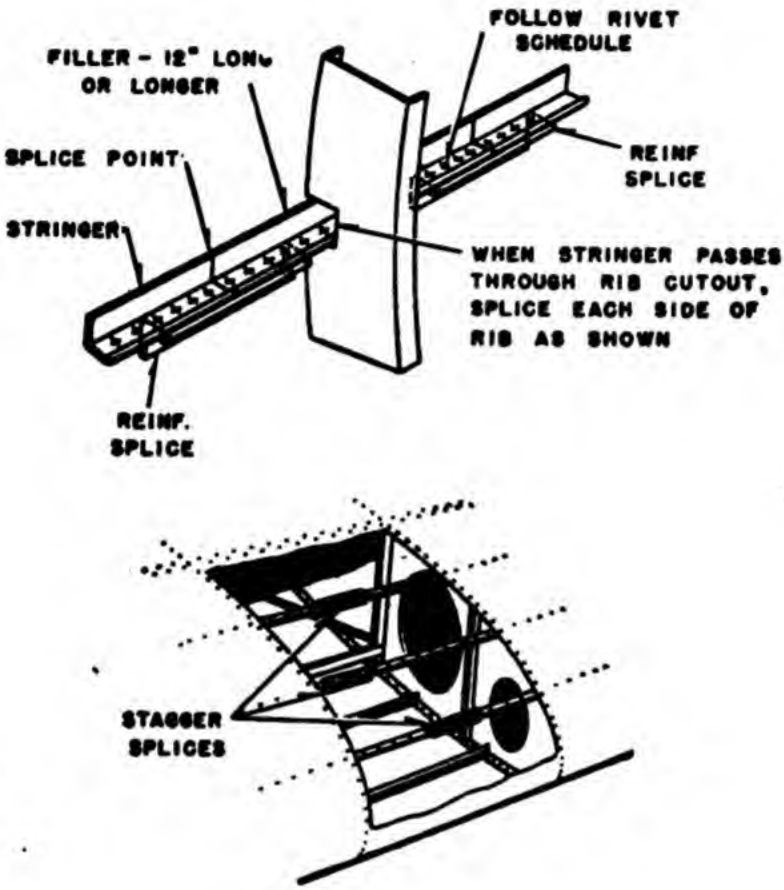


Figure 108.—Staggered splices.

The REINFORCEMENT SPLICE, to be used with the filler splice, should be long enough to extend at least four times the width of the stringer on each side of the damaged area. Figure 110 shows the completed assembly with filler and reinforcement splices in place.

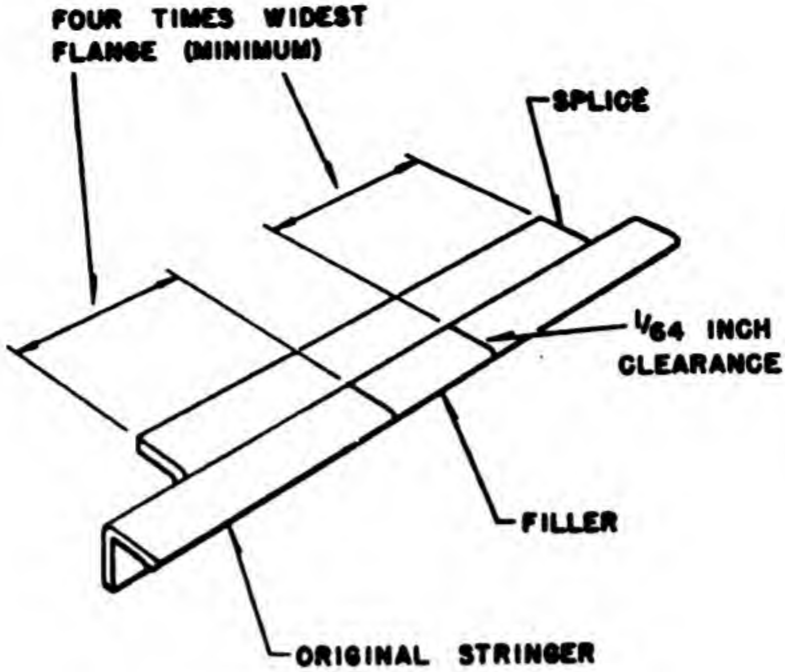


Figure 109.—Filler splice.

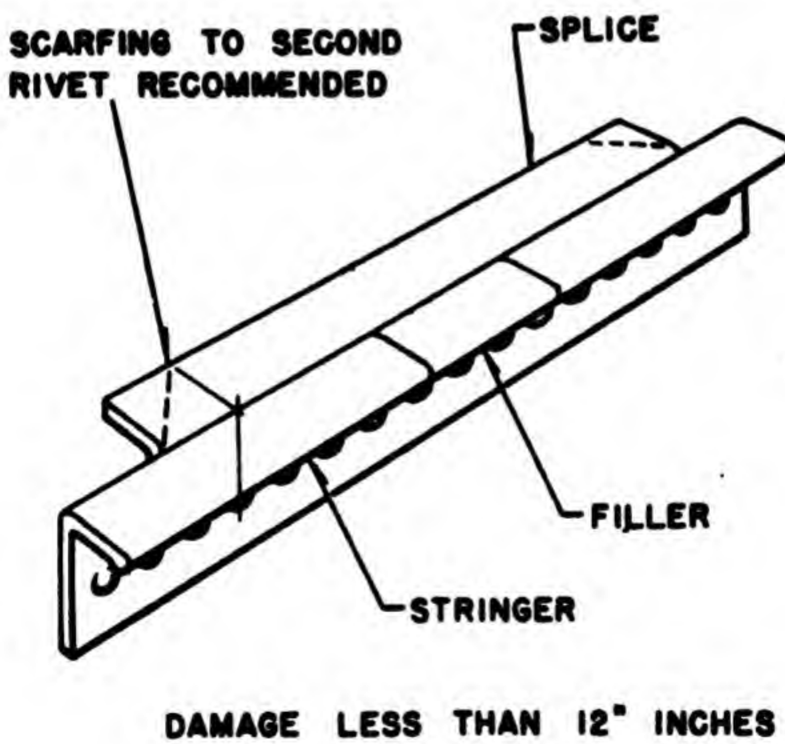


Figure 110.—Bulb angle repair, using filler and reinforcement splices.

An important consideration in repairing a cracked or damaged stringer is the number of rivets necessary to reinforce the angle on each side of the crack. Since stringers and reinforced angles vary as to shapes and sizes, it is difficult to set down any general rules.

The materials of which stringers are made all have specific allowable loads which they can carry. For most types of repairs and for most stringer materials, the figure of 43,600 pounds per square inch is considered to represent the allowable stress.

Based on this figure, chart 16 indicates the approximate number of rivets which you will need on each side of the damaged area.

Thinnest sheet 24S–T gage material	Rivets, 1/8 inch		Rivets, 5/32 inch		Rivets, 3/16 inch	
	A17S–T	17S–T	A17S–T	17S–T	A17S–T	17S–T
0.020	3.9	3.9	....	....	....	....
.025	3.9	3.9	....	....	....	....
.032	4.5	3.9	3.1	3.1	....	....
.040	5.7	4.7	3.6	3.1	2.6	2.6
.051	7.3	6.1	4.6	3.9	3.2	2.7
.064	9.0	7.6	4.8	4.0	3.3	2.8

Figures under "rivet" columns represent the number of rivets required per inch of damaged cross-sectional width.

Chart 16.—Required rivets for stringers.

As an example of this chart's use, let us consider figure 111, which shows a crack in the channel section of the stringer. This section is 3 inches across and 3/4 inch up on each side, making a total crack length of 4 1/2 inches. The metal is 0.032, 24S–T rib, demanding 1/8-inch 17S–T rivets. This indicates, through use of chart 17, that 3.9 rivets per inch of cracked damage will be required.

Multiply 3.9 by 4 1/2 inches, and the figure 18 is obtained—the number of rivets required on each side of the damage.

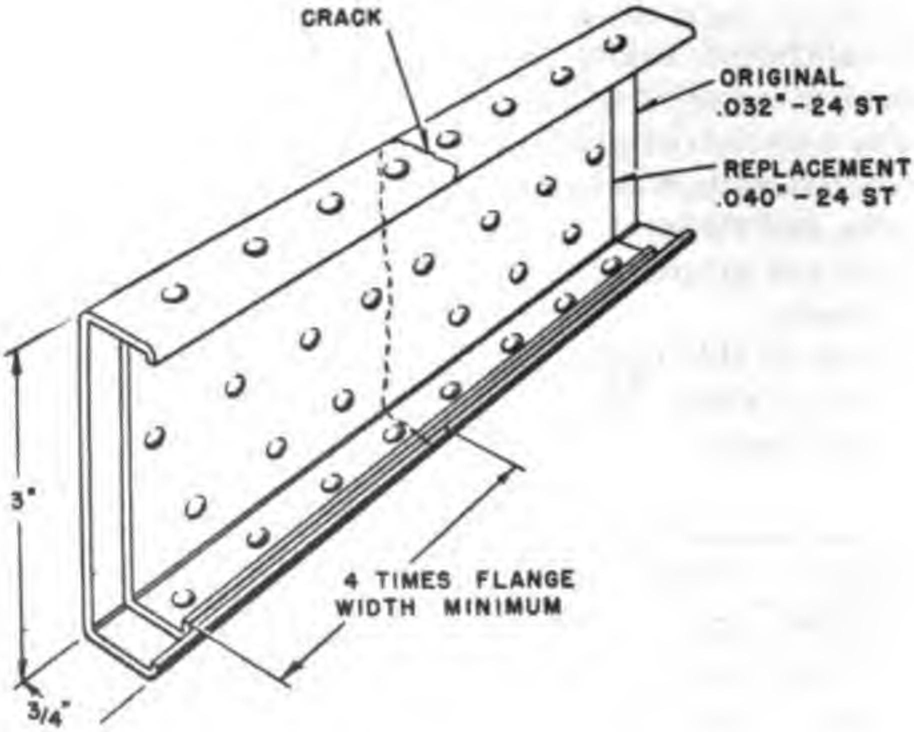


Figure 111.—Typical channel repair.

Locate and drill holes in the reinforcement plate according to the standard riveting rules. The edge distance measured from the center of the rivet to the edge of the sheet should be two times the rivet diameter. The spacing between rivets should equal three to four times the rivet diameter. It may be necessary to insert additional rivets at the end of the stringer and at the ends of the filler block.

When the rivet holes have been drilled through the reinforcement plate, clamp the filler plate to it and drill matching holes through the filler plate.

Figures 112, 113, and 114 illustrate a number of typical repairs to formed angle stringers, and figure 115 illustrates typical repairs to extruded angle stringers.

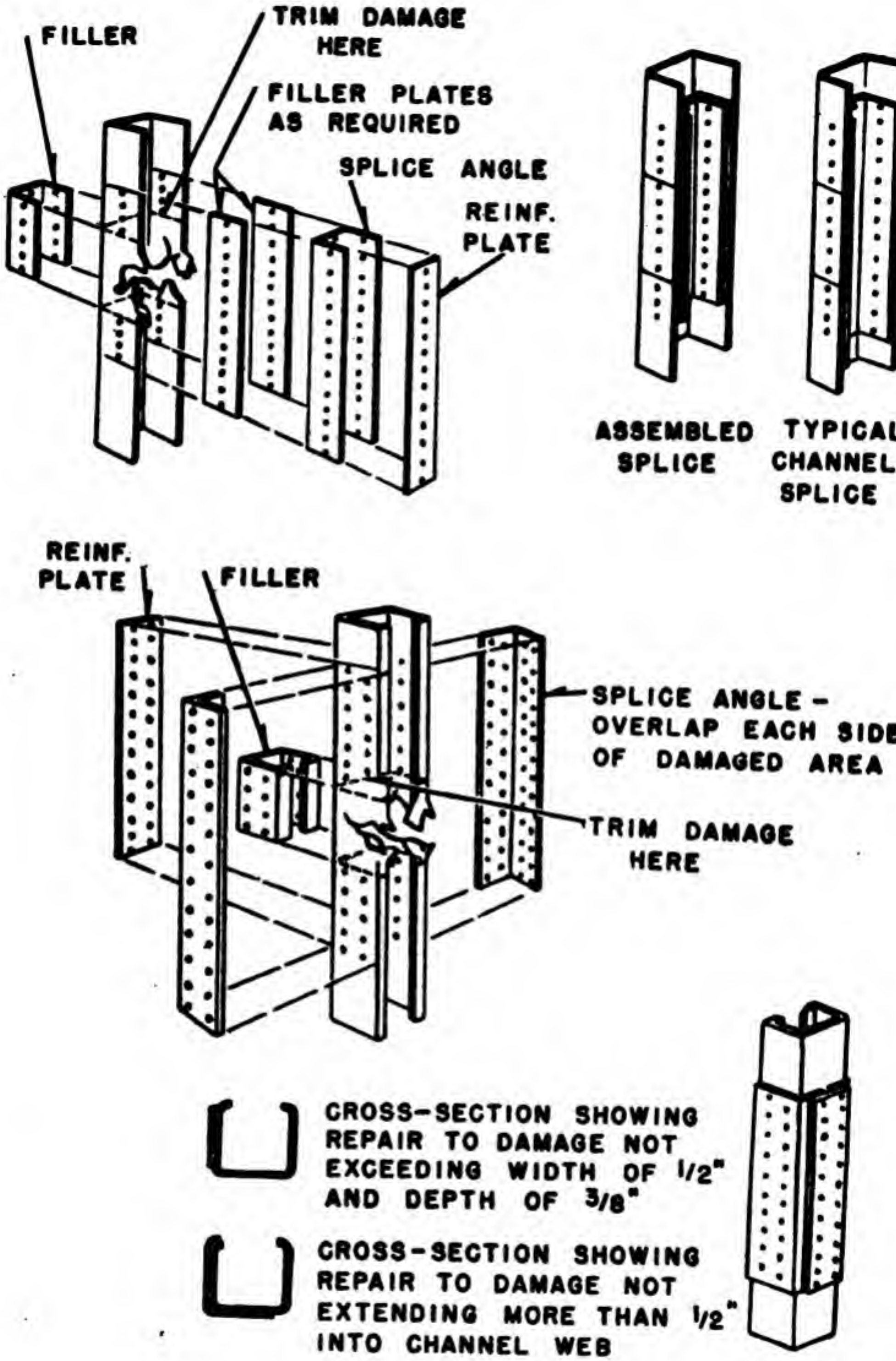


Figure 112.—Splicing damaged channel webs.

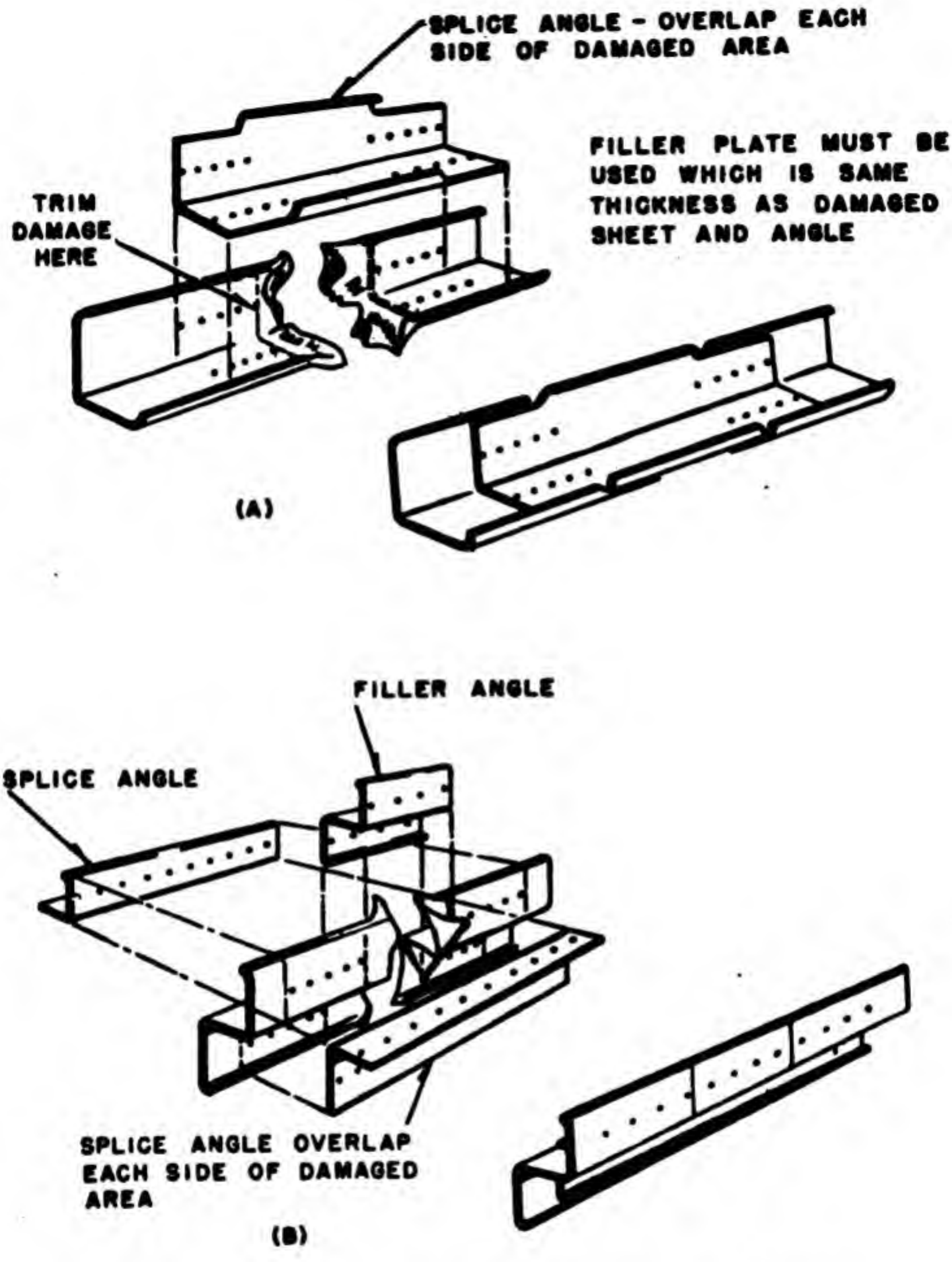


Figure 113.—Splicing damaged bulb angle and Z-stringers.

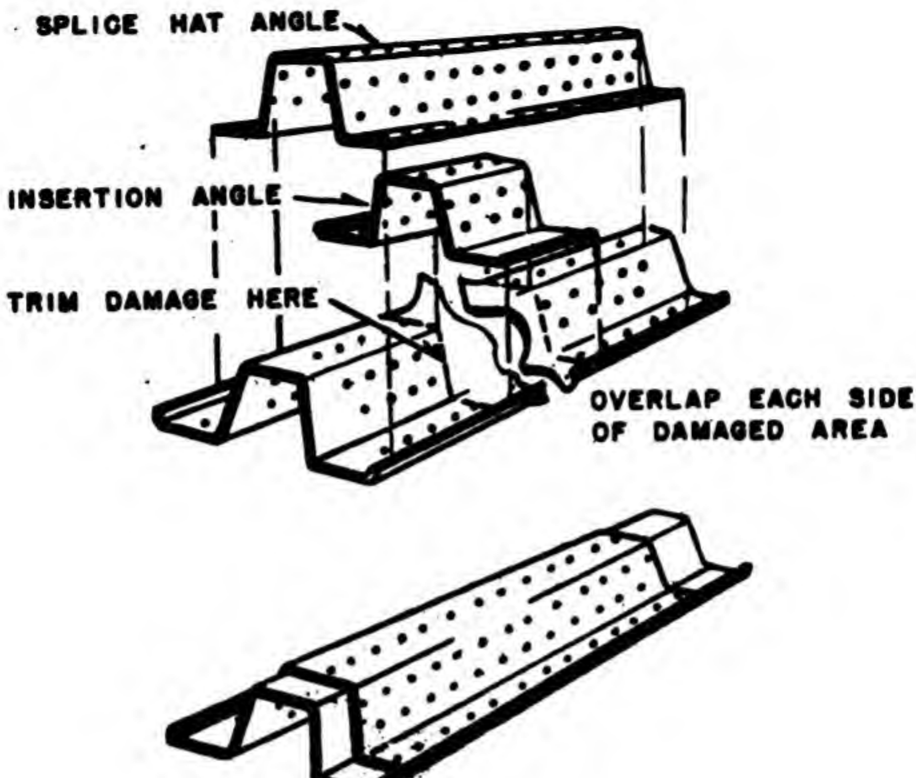


Figure 114.—Splicing a damaged hat angle.

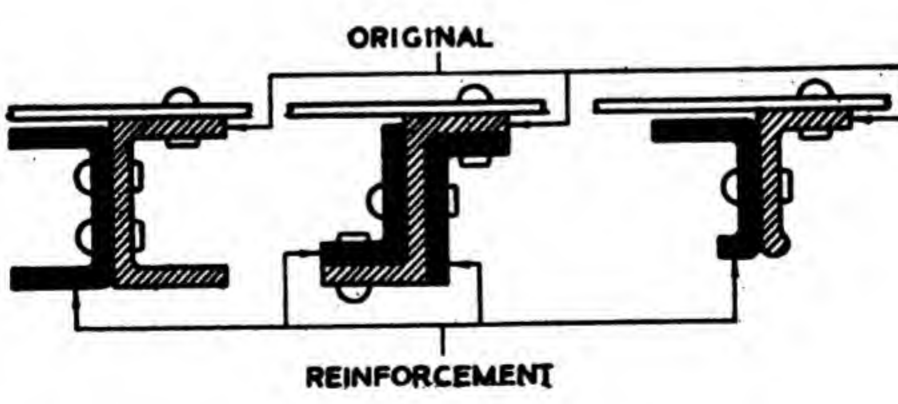


Figure 115.—Typical repairs to extruded angles.

Spars are spanwise members which run the entire length of the wing. Since their purpose is to carry the bending loads imposed on the wing, all repairs must be made so that no loss of strength will occur.

Due to the variety of spar construction, it is impossible to discuss all of the designs, however, most of them are composed of two parts, known as FLANGES and WEBS. The flanges are generally referred to as the top and bottom parts of the spar, and the web as the center section, as is illustrated in figure 116. Small spars and reinforcements are made by forming a strip into a channel shape. The top and bottom serve as the flanges, and the upright section as the web, as shown in figure 116.

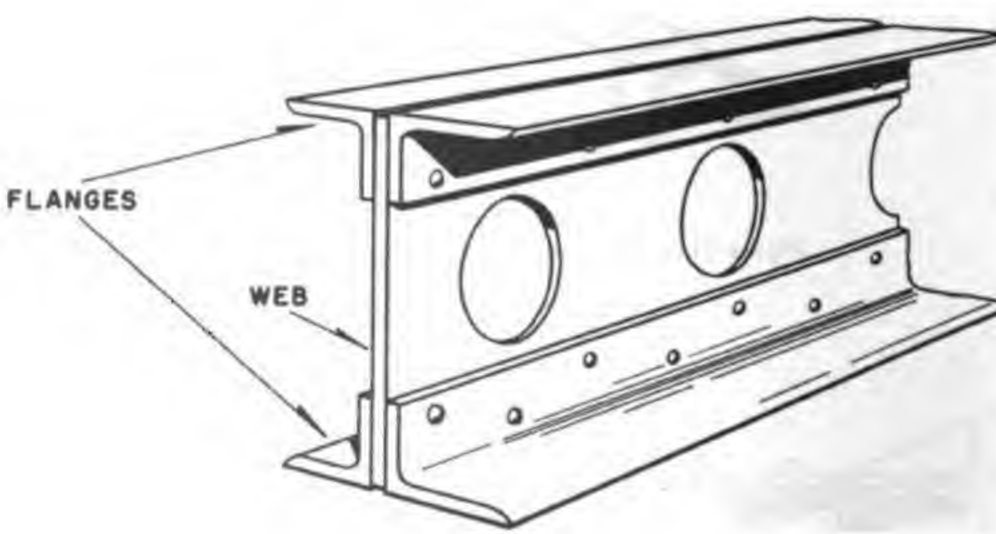


Figure 116.—Spar flanges and webs.

Cracks in Spar Webs

Cracks in spar webs may be repaired in the same manner as those in any stressed skin section. A small hole is drilled at each end of the crack and a suitable patch is riveted over it, as may be seen in figure 117.

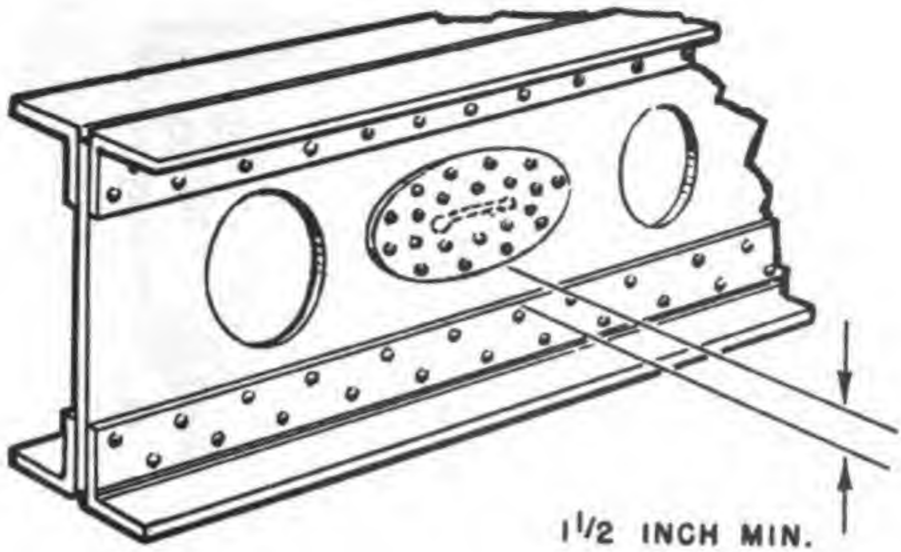


Figure 117.—Patching a crack in a spar web.

Holes in Spar Webs

Holes in webs generally occur as the result of bullet or cannon fire. It is impossible to outline all of the damages, but the repair procedure discussed here will apply to most cases. Figure 118 shows some typical repairs to holes in spar web members that will aid the aviation structural mechanic in repairing similar damage.

If the damage occurs near a lightening hole, cover the hole by placing the patch on the side opposite the hole's flange.

Two repair methods are illustrated in figure 119. If damage to the web extends almost into the flange, cut away the damaged area and use splices on both sides of the web shown in the cross section (C–C) at top left in the drawing. If damage to the web is small, the procedure shown at (B) may be employed.

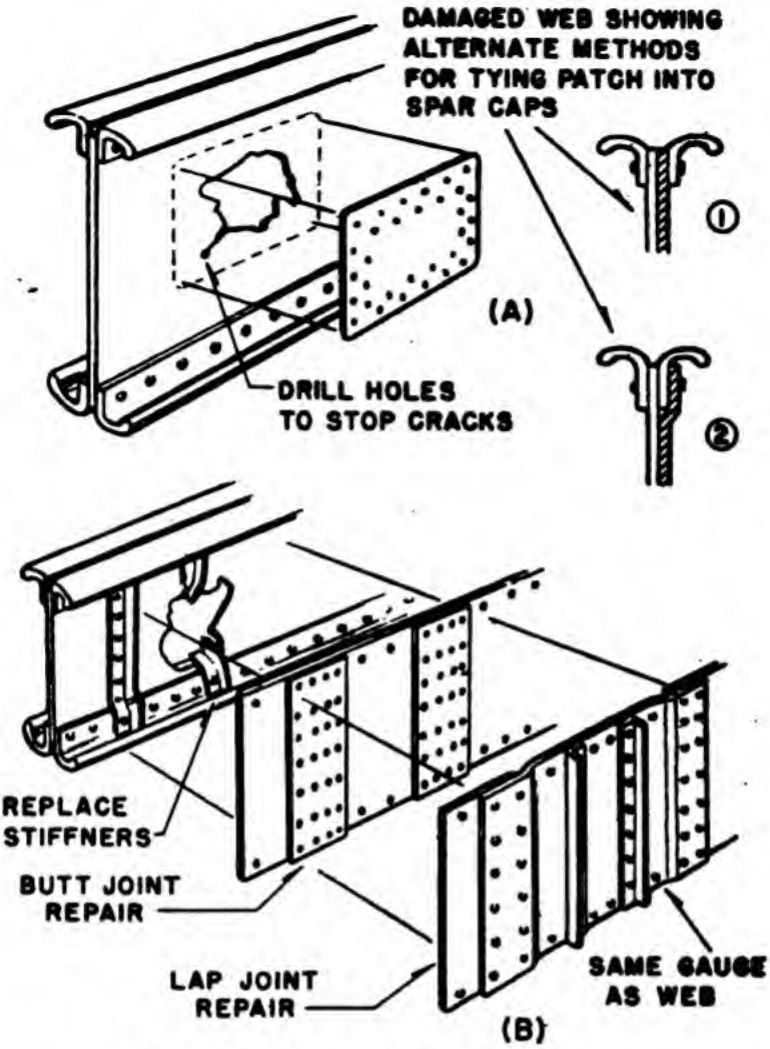


Figure 118.—Repairing holes in spar webs.

Figure 120 shows a repair to a spar where the damaged section is removed, but where a filler is not used except at the top and bottom of the flange, where the spar is attached to the skin. These two insertion fillers at the top and bottom of the flange are necessary so that the rivet pattern can be followed. It will be noted that a split reinforcing splice is employed. After this splice is riveted to the spar, it is stiffened by the addition of an angle riveted to it.

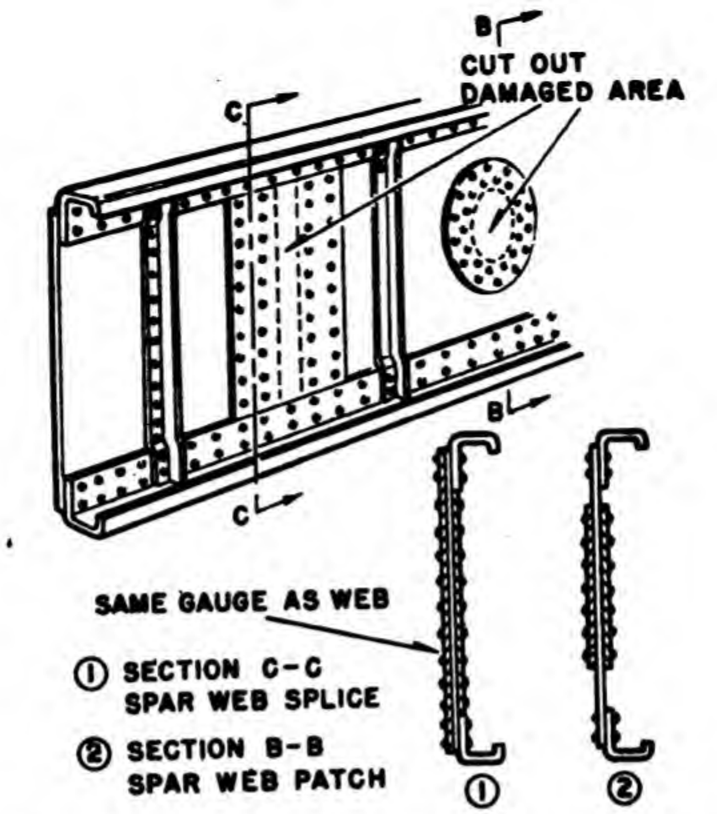


Figure 119.—Two methods for repairing a damaged web.

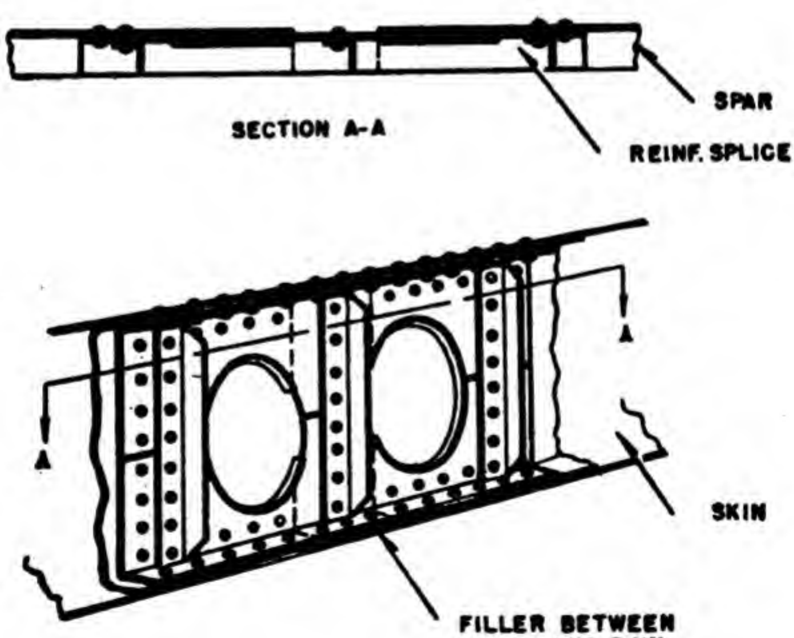


Figure 120.—Use of two insertion fillers.

DAMAGED SPAR FLANGES

Damage to flanges usually extends into the web, making it necessary to repair both parts. If the spar is of the channel type, flange and web repairs must be made together. Figure 121 illustrates a typical repair to a channel spar using the split reinforcing splice and filler. The splice must be split because a single-piece splice could not be inserted into the channel. Figure 122 shows several ways to repair a spar which has a tear in the flange.

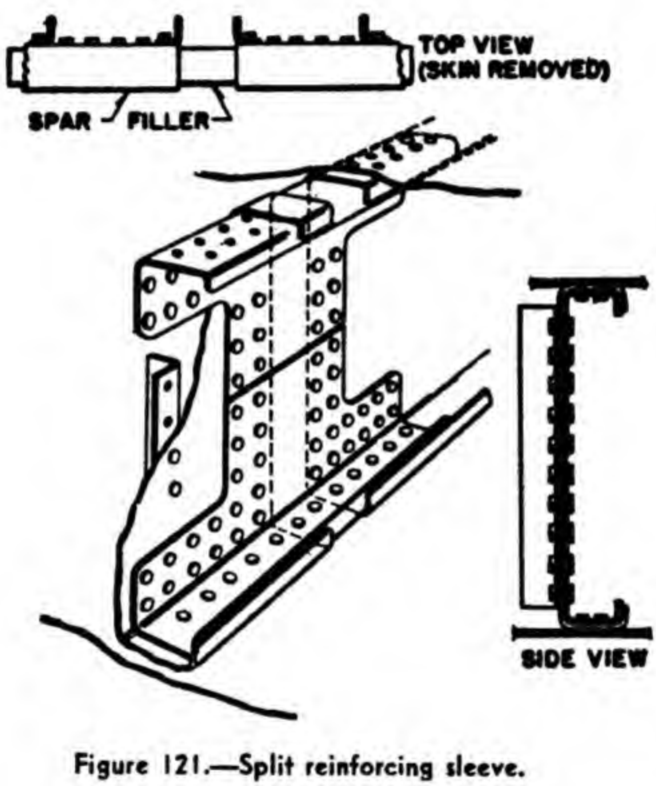


Figure 121.—Split reinforcing sleeve.

REPAIR OF RIBS

Wing ribs, in addition to maintaining the shape and rigidity of the wing, are designed to pass along wing loads from the skin to the spars. They are required to resist compression as well as shear loads.

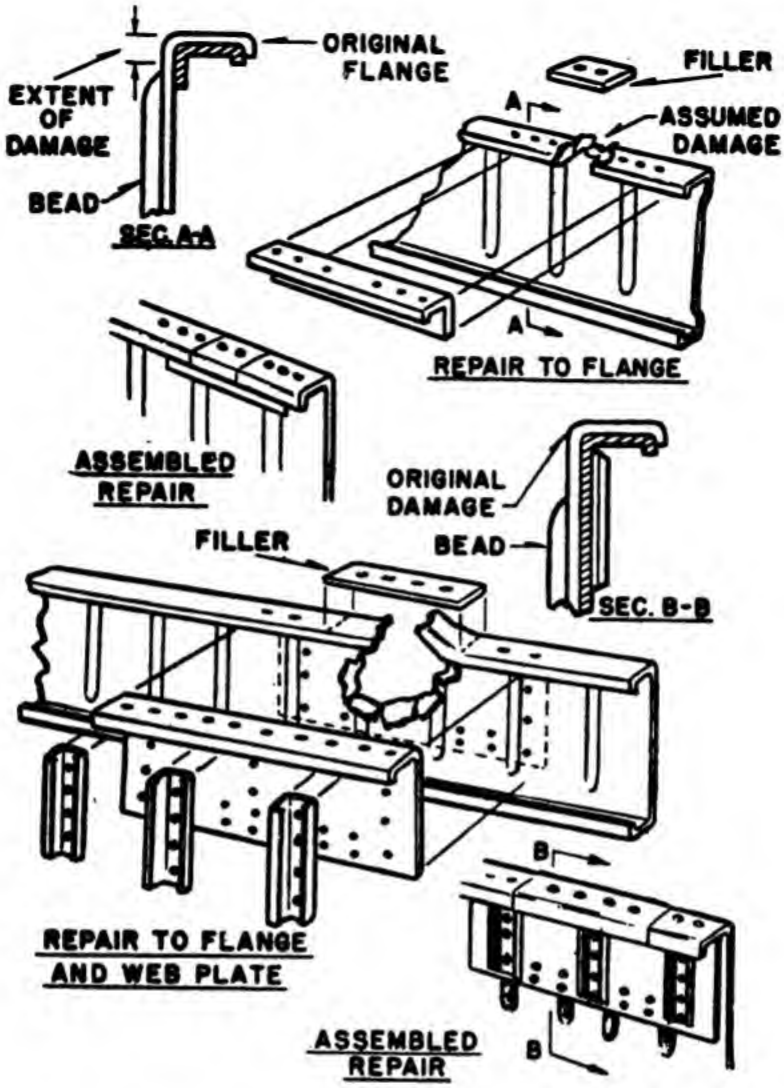


Figure 122.—Repairing spar with torn flange.

Ribs are most generally of three types of construction—the trussed rib type, the type with bentup sheet flanges and with flange holes in the web, and the solid web ribs with extruded angles or channel stiffened flanges. These three types of ribs are illustrated in figure 123.

Figure 124 shows typical repairs to damaged capstrips found in the trussed rib.

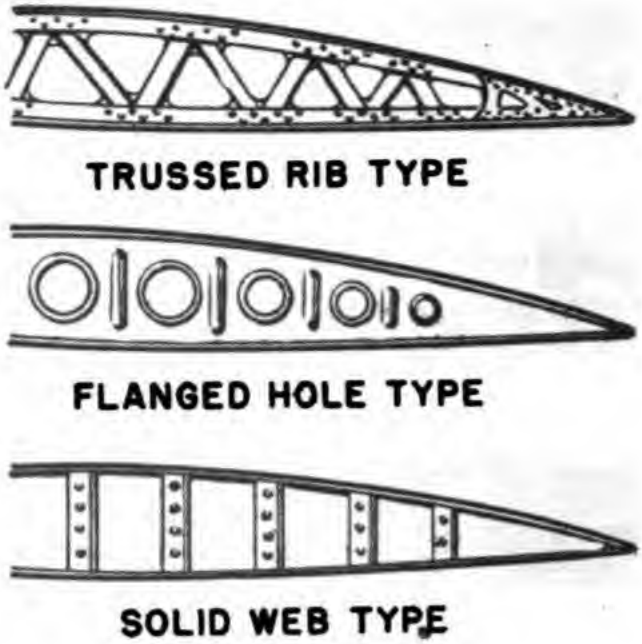


Figure 123.—Wing ribs.

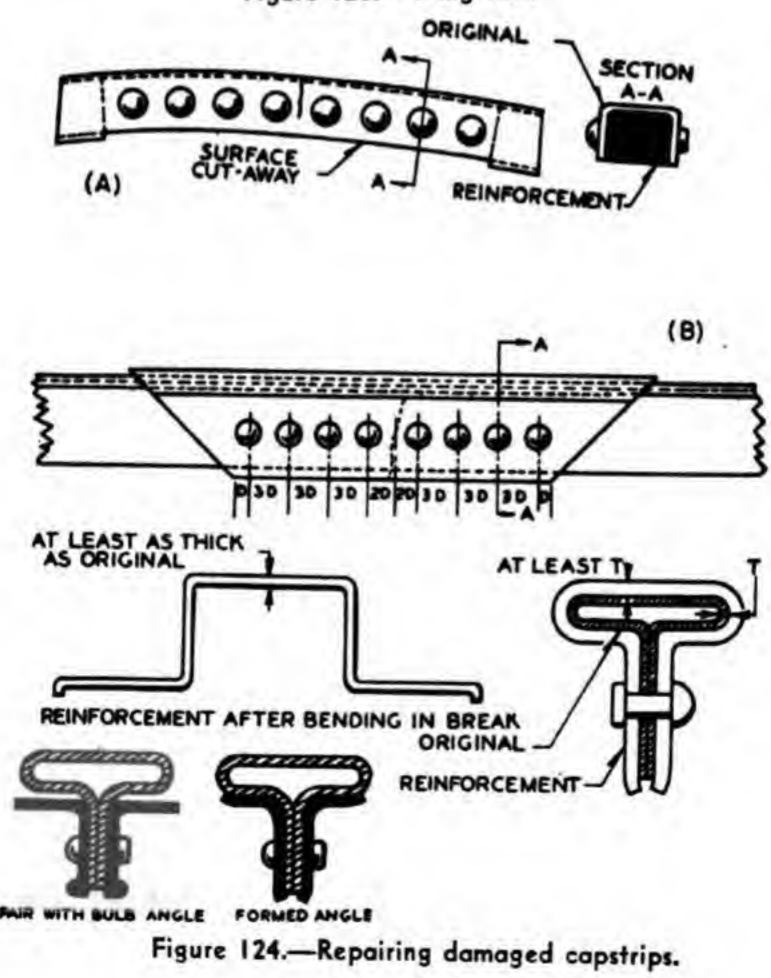


Figure 124.—Repairing damaged capstrips.

In figure 125 (A) is pictured a typical repair of buckled rib webs, and in figure 125 (B) a typical rib splice.

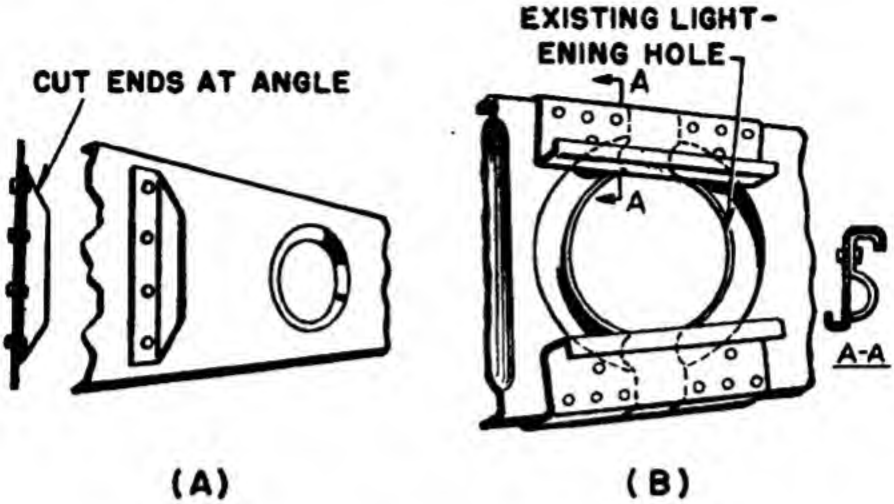


Figure 125.—Repairing wing rib webs.

In figure 126 you see a typical rib flange repair where the flange is riveted to the skin. Figure 127 illustrates a repair of broken rib beads.

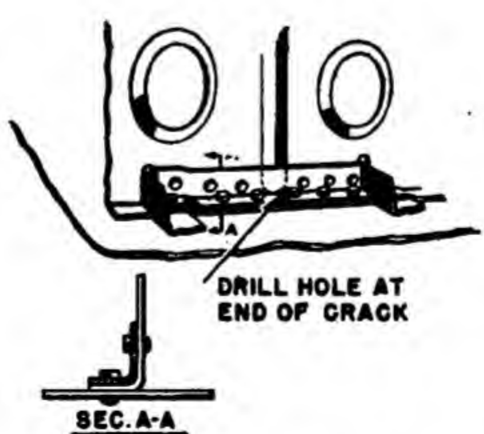


Figure 126.—Repair of flange riveted to skin.

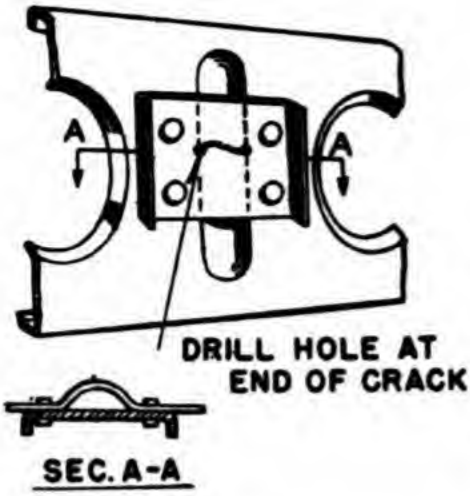


Figure 127.—Repair of broken rib beads.

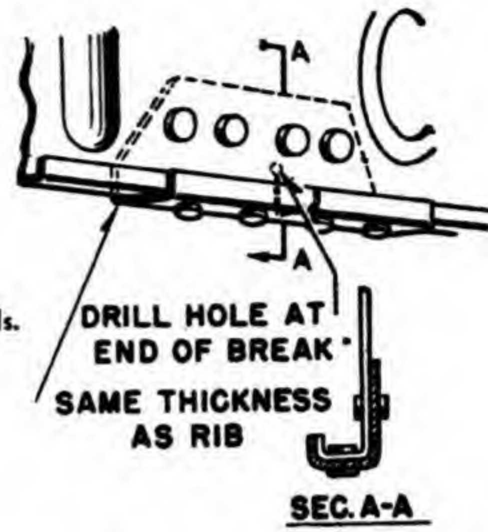


Figure 128.—Repair of flange not riveted to the skin.

A typical repair of a cracked rib flange where the flange is not riveted to the skin, is shown in figure 128. Figure 129 pictures a typical reinforcement to a cracked lightening hole.

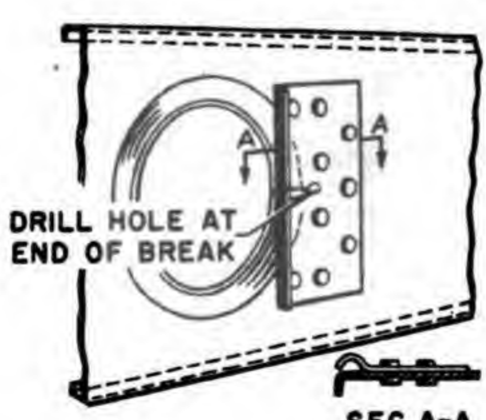


Figure 129.—Repair of cracked lightening hole.

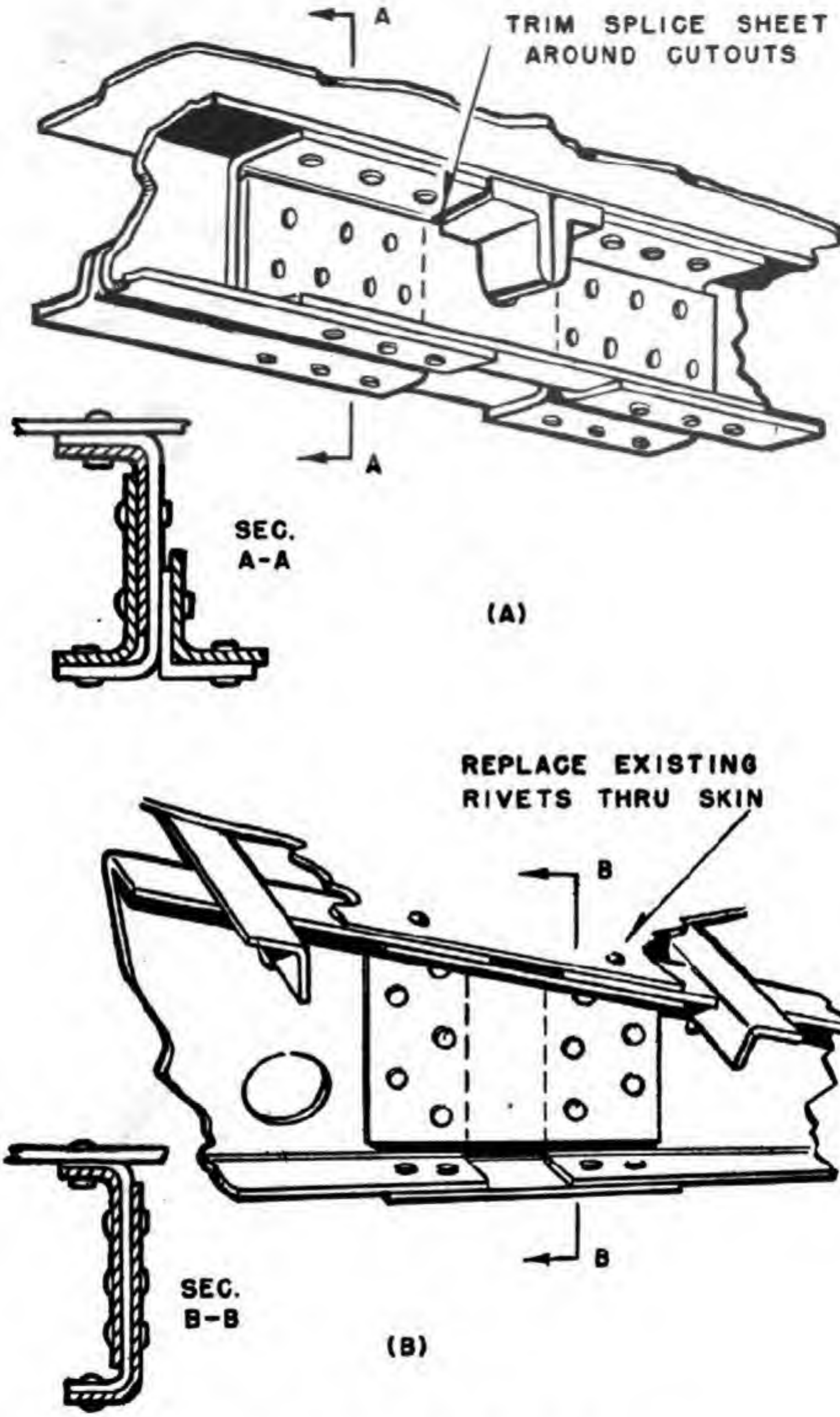


Figure 130.—Splicing of wing rib sections.

A center section of a wing rib may be spliced as shown in figure 130 (A). A typical trailing edge rib splice is demonstrated in figure 130 (B).

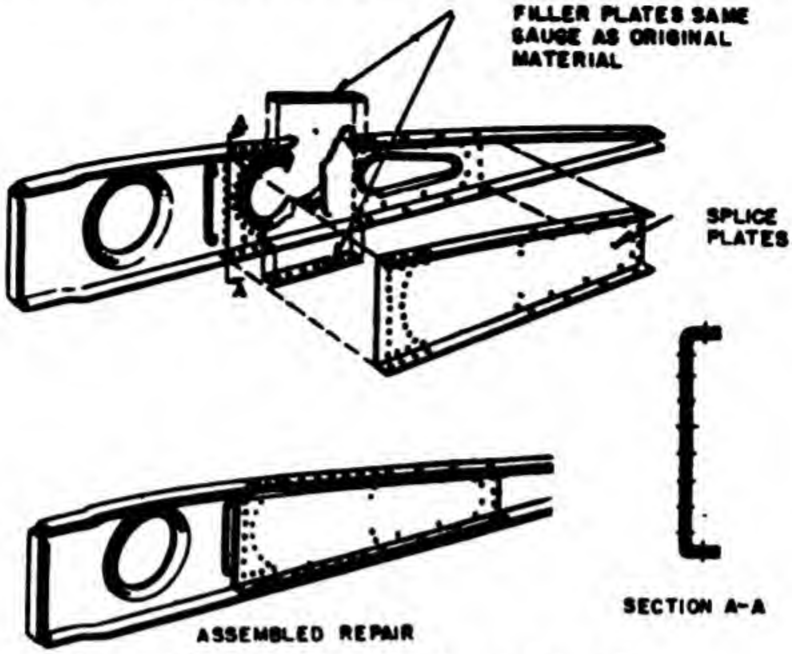


Figure 131.—Typical repair of a wing flap rib.

Figure 131 is a picture of the repair to a wing flap rib.

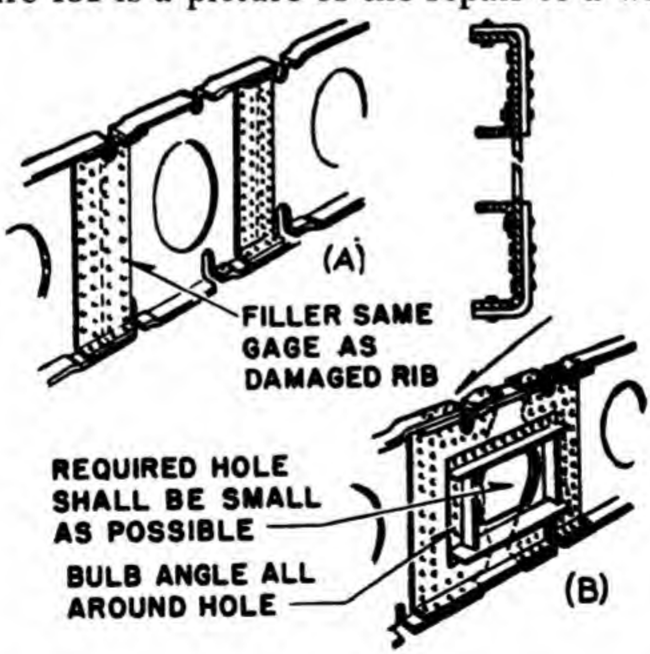


Figure 132.—(A) Splice for damage greater than 5 inches. (B) Field repair when hole is needed.

Repairs to wing leading edge ribs are shown in figures 132, 133, and 134.

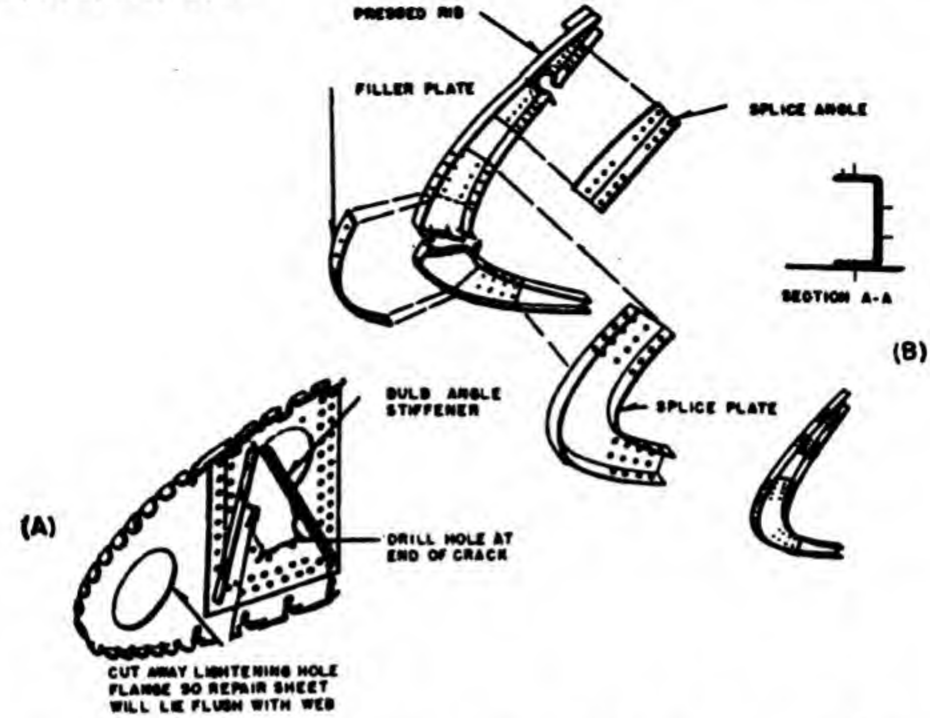


Figure 133.—(A) Repair of partial damage. (B) Repair to leading edge rib.

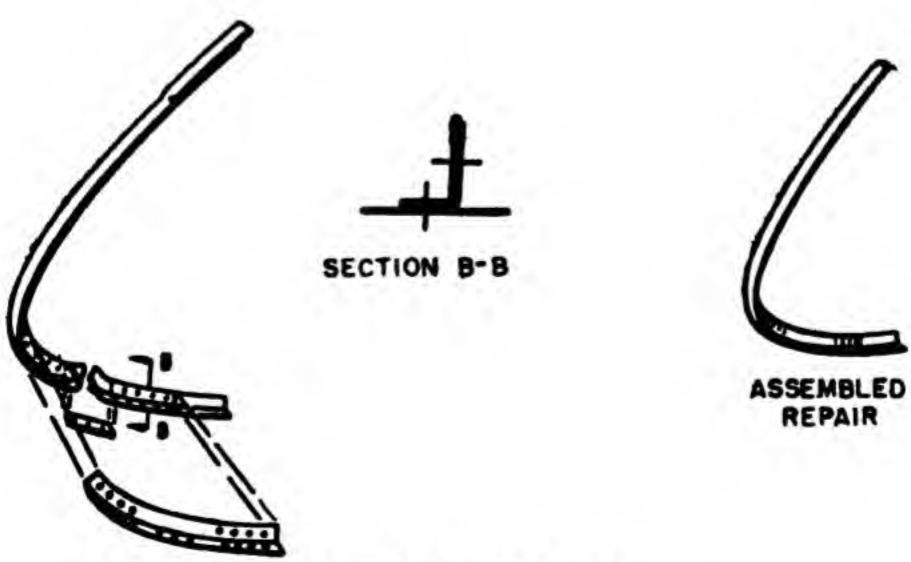


Figure 134.—Repair to former.

The true definition of the word "bulkhead" refers only to the solid type partition, whether or not it be watertight, which separates the various compartments of an aircraft fuselage, hull, or float. In this sense, reinforcing rings, former rings, and belt frames are bulkheads.

The main purpose of a bulkhead is to maintain the shape of a fuselage, float, or hull, and absorb part of the stress which is transmitted from the skin and the stringers.

Bulkheads are usually constructed of formed sheet metal or of extrusions formed to the desired shape. However, in some construction a combination of sheet metal and extrusions are used.

The following illustrations show various methods that might be used in repairing damage to bulkheads.

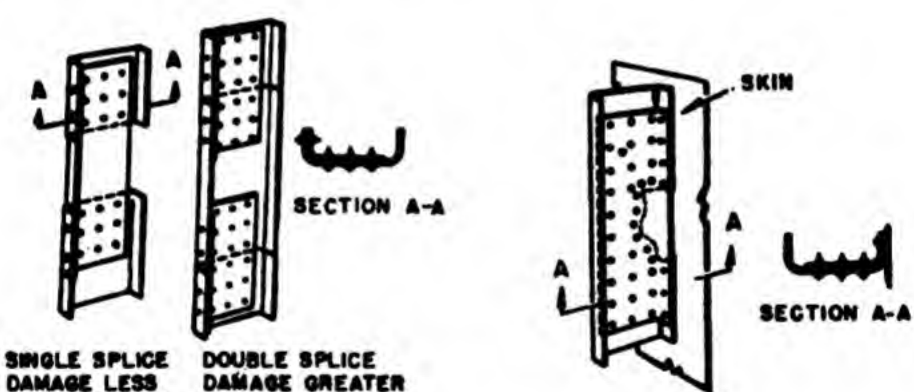


Figure 135.—(Left) Total repairs for frames 0.040, 0.051, and 0.064 inch in thickness. (Right) Partial repair for all frames.

It must be borne in mind that the repairs illustrated are typical repairs to the various types of bulkheads. Due to the many types of construction, there can be no set rule for repair; however, the ones shown are the more common types.

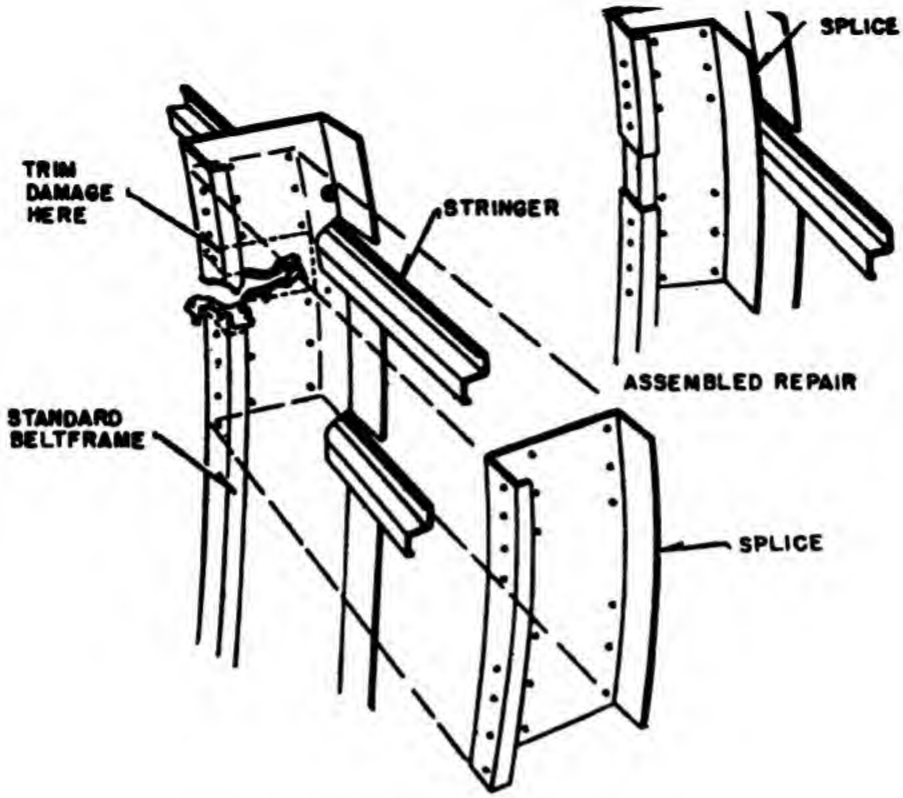


Figure 136.—Repair for standard belt frame.

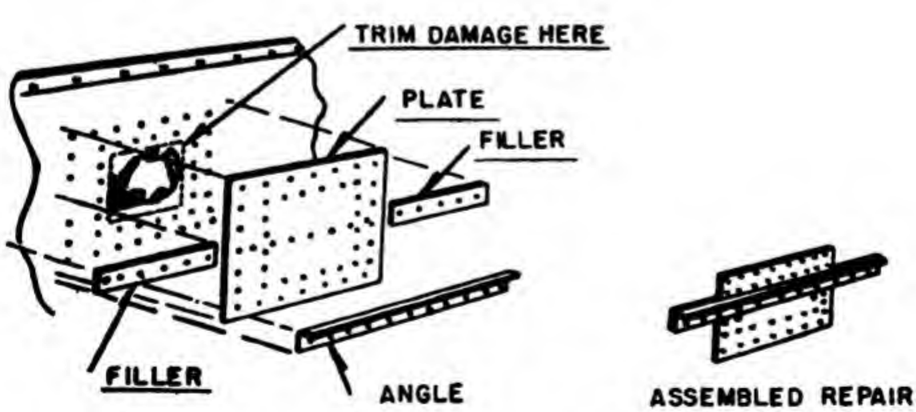


Figure 137.—Web repair on bulkhead.

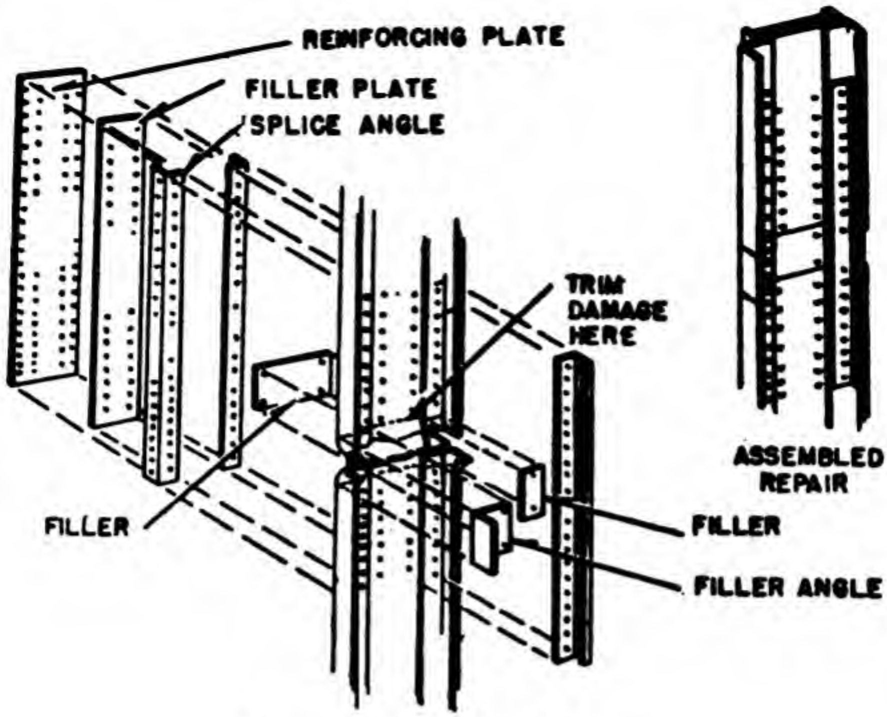


Figure 138.—Repair of stringer.

TRAILING EDGE REPAIR

A trailing edge is the rearmost edge of an airfoil—that is, a wing, aileron, rudder, elevator, or stabilizer. It is generally a metal strip which forms the shape of the edge by tying the ends of a rib section together and joining the upper and lower skins. Trailing edges are not structural members, but nevertheless considered as being lightly stressed in all cases.

Kinds of Trailing Edge Repair

Trailing edges may be covered with either metal or fabric, depending on the relative importance of the rigidity and weight required by the airfoil. Most control surfaces are covered with fabric in order to reduce their weight, thus rendering operation easier and the controls more accessible, and reduce vibration of the airfoil. Metal covered control surfaces have more flutter or vibration, which makes the operation of the controls more difficult.

The rod type of trailing edge is generally used on small fabric covered control surfaces. Damaged sections of rod must be replaced from wing rib to wing rib and fastened in place with metal clips.

Tubing is used in place of a rod for a trailing edge in larger fabric covered control surfaces. This edge probably can best be repaired by the insertion of a solid reinforcement splice and riveting the original tubing to it. The tubing may be spread at the break, or part of its surface may be cut away in order to insert the splice. Figure 139 shows a reinforcement splice inserted in a cracked tubing trailing edge.

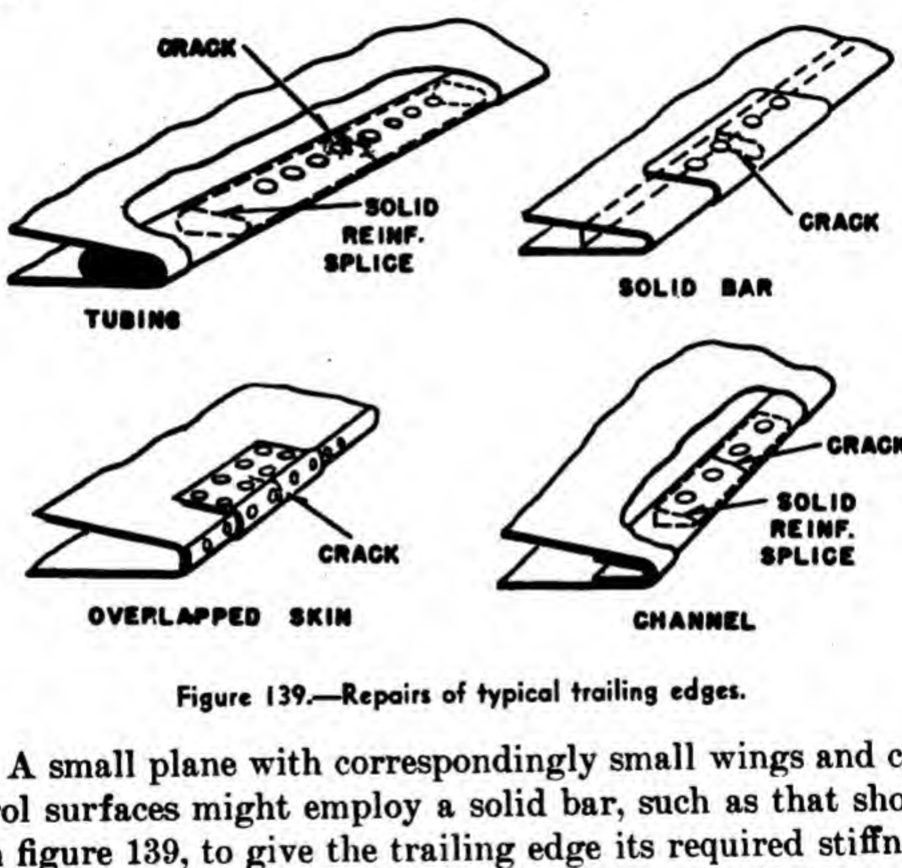


Figure 139.—Repairs of typical trailing edges.

A small plane with correspondingly small wings and control surfaces might employ a solid bar, such as that shown in figure 139, to give the trailing edge its required stiffness. These bars are used in airfoils which are covered with metal skin, and are repaired by simply fastening a reinforcement splice or patch of sheet stock over the crack.

An overlapped skin trailing edge is found in some metal covered airfoils. In such cases, the upper and lower skin surfaces are overlapped sufficiently to permit them to be

riveted together. This type of trailing edge may be repaired by using a reinforcement patch of sheet stock which is joggled to conform to the contour of the overlapping skins, as shown in figure 139.

The channel type is probably one of the most commonly used trailing edges, and is used in both metal and fabric covered airfoils. Channel repairs are discussed in detail under "Procedure" because they involve a number of typical operations.

The damage to trailing edges of wings, control surfaces, or flaps may be limited to one point or may extend over an entire length between two or more rib sections. Damage caused by gunfire, collision, ground looping, or careless handling results in buckling, cracking, or holes. Corrosion is not always apparent, but it must be remembered that trailing edges are particularly subject to it. Moisture tends to be trapped in the trailing edge part of the wing when the drainage holes become clogged.

A thorough inspection should be made of the damaged area before making repairs in order to determine the extent of the damage, the type of repair to be made, and the manner in which it should be performed.

If the damage constitutes a crack or break in the trailing edge, it may be restored to its original strength with a reinforcement splice or patch. The shape and type of reinforcement will be determined by whether the airfoil is covered by metal or fabric. When the reinforcement is to be made from an extruded shape, it should be of the same contour and temper as the original in order to restore the initial strength. For trailing edges with a small radius, the splice may be most easily made of solid material, such as aluminum alloy, micarta, or bakelite.

In cases where the reinforcement must be made of sheet stock, it should be one gage heavier than the original member, of the same temper, and must be formed to fit the original.

Damage to a trailing edge may extend over such an area that a section of it must be removed and replaced. In this

case, the new section must be of size, shape, and temper to duplicate the original. It may be an extruded shape or it may be formed from sheet stock, depending upon the available material. Figure 140 illustrates a new section inserted in a trailing edge.

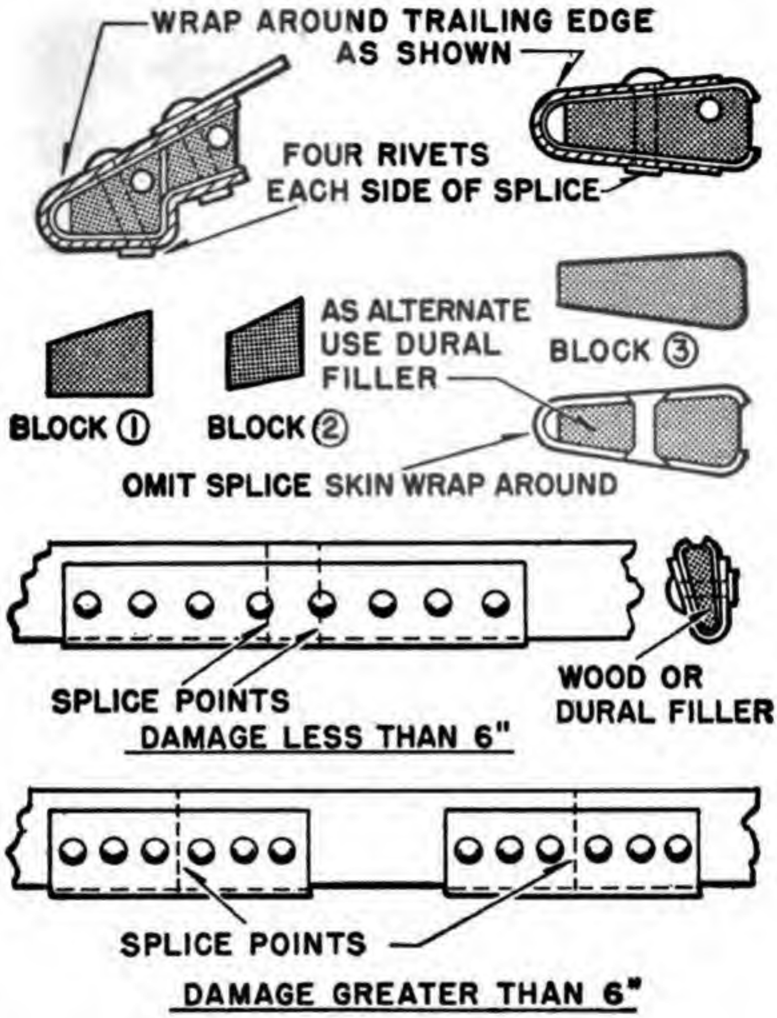


Figure 140.—Repair of trailing edge by inserting a new section.

The actual procedures for making the repairs just described are so many and varied that only one can be presented in detail. The repair of a formed channel strip, of the type shown in figure 140, may be used as a model for the repair of most trailing edges.

Cut away the damaged area if it is badly crushed or distorted. If it is merely cracked, straighten the damaged part and insert a reinforcing splice.

Determine the length of the section to be replaced. If the new section is to be formed from sheet stock, cut a piece of the same material and gage as the original trailing edge when figuring the length.

Form the new section to the same shape as the original in a cornice brake.

Burr all edges and slightly round the corners, on both the new section and the exposed ends of the original.

Cut a reinforcement splice of the same metal and one gage heavier than the original. The length of the splice is normally determined by the width of the trailing edge section. The reinforcement splice should extend at least 1½ times the width of the trailing edge section on each side of the break or joint. Since this repair is on a nonstructural part, the rivet spacing should be about 8D, as shown in figure 141.

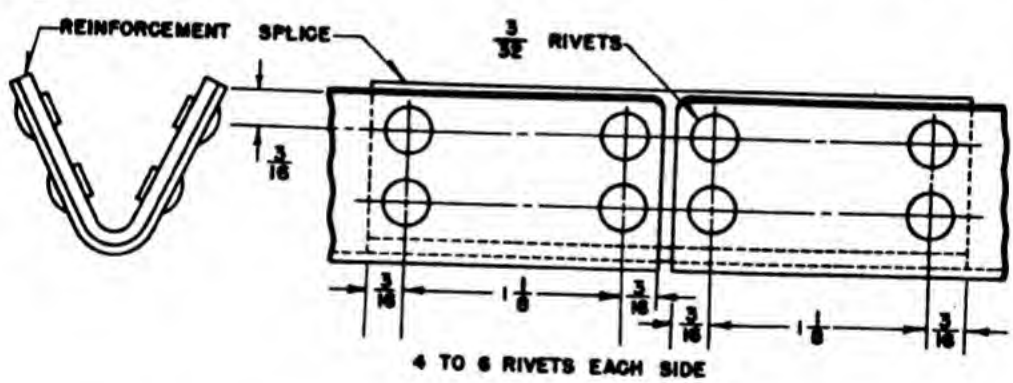


Figure 141.—Rivet spacing in trailing edge channel-type repair.

Mark the rivet location on the reinforcement splice. If necessary, they may be staggered in order to head the rivets.

Clamp the new section and the reinforcement splice together and drill the holes.

Temporarily fasten the pieces with sheet fasteners and then rivet together. Figure 142 illustrates a repair in which a solid filler block is employed.

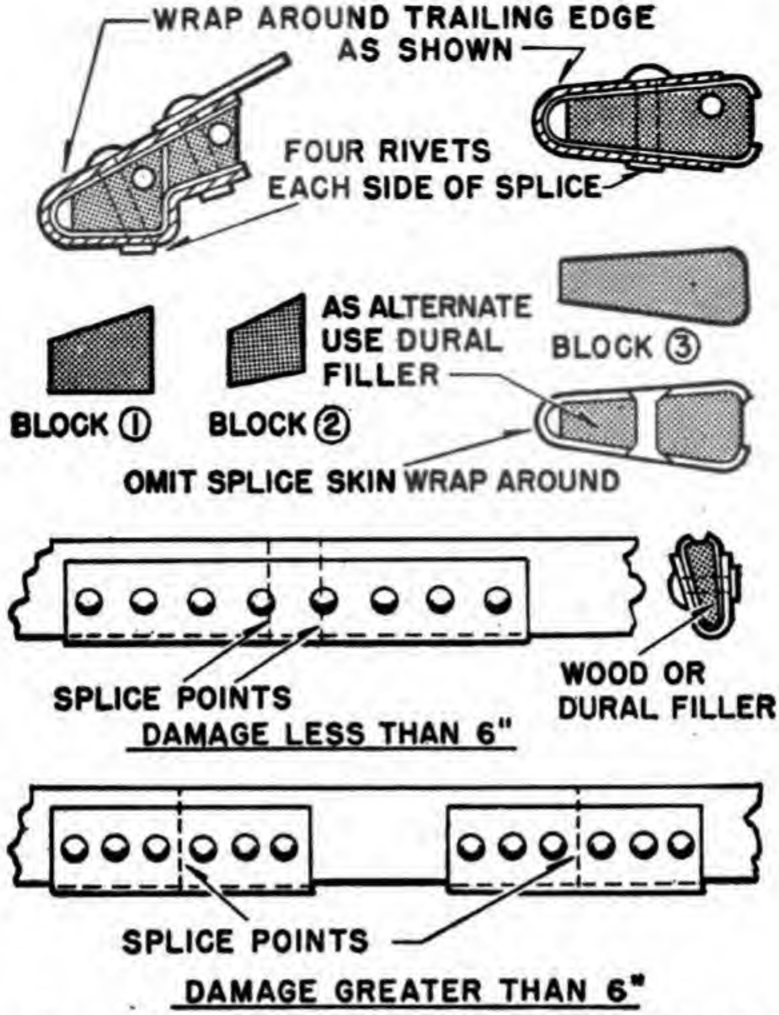


Figure 142.—Trailing edge repair employing solid filler block.

SKIN REPLACEMENT

The skin of a modern high-powered aircraft is an important structural member since it gives shape to the different parts of the airplane and aids the reinforcing members in carrying stresses. For this reason, repairs to the skin must restore the original strength to the same extent as repairs to ribs, bulkheads, spars, or stringers. The skin, being on the surface, is exposed to damage from various sources. Sometimes the damage is so extensive that an entire panel must be replaced. Obvious causes of such damage are gunfire or collision; others are not so apparent. For example, the protective coating on the skin of a seaplane may be

broken, resulting in rapid corrosion which may damage the skin beyond repair. Vibration sometimes causes skin failure. Such a condition is evident only when a thorough inspection is made. Finally, an excessive number of patches or minor repairs on a section or panel of a fuselage, wing, or control surface may require the replacement of that panel.

Inspection

Inspect the damaged area thoroughly to determine injury other than obvious skin failure. The paint around the damaged area must be removed so that the cracks or other indications of stress can be seen. A paint remover or solvent should be used that will not injure the corrosion-resistant coating.

Inspect the reinforcing rings or stringers for damage or signs of strains. Such members, when bent, fractured, or wrinkled must be replaced or repaired. Rivets in the area must be inspected for signs of failure. They may be sheared considerably without visible evidences of such a condition. Drill out rivets at various points in the damaged area and examine them for signs of shear failure. Figure 143 shows a sheared rivet which will fail if not replaced.

When the extent of the damage has been discovered, the size of the new sheet may be determined. If the damage is not sufficiently great to require replacement of the entire original panel, it should extend at least from one reinforcement to another, as shown in figure 144.

Note carefully all unusual riveting problems—conditions which render riveting difficult or which make replacement impossible. Time spent in inspection will be worthwhile even if indicating nothing more than the fact that repairs must be done at an O & R shop or at the factory because of the special tools required.

Any fixtures which will hinder riveting and prevent the use of straight bucking bars will be apparent in a thorough inspection. There will also be places where flanges or reinforcing members, or the intersection of stringers and rings, make the bucking of rivets very difficult. This problem can

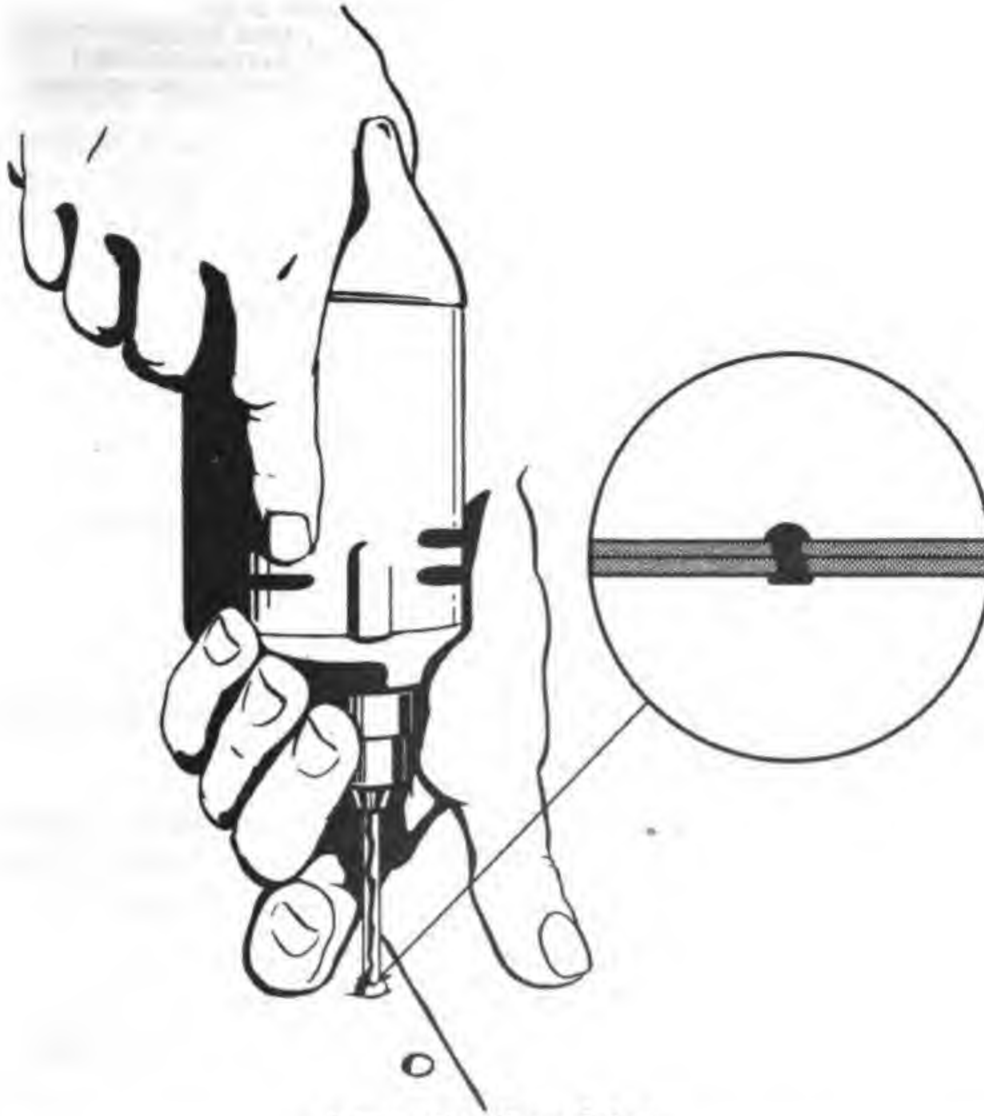


Figure 143.—Sheared rivet.

be solved by designing and making bucking bars to suit these particular situations.

Care must be taken to avoid mutilating the damaged skin in the process of removal, because in most cases it can be used as a template for layout of and drilling holes in the new pieces of skin.

The rivet holes in stringers, bulkheads, rings, and so on, must be kept in as good condition as possible. If any of the reinforcing members are loosened by the removal of rivets, their location should be marked so that they can be returned to their original position when the repair is made.

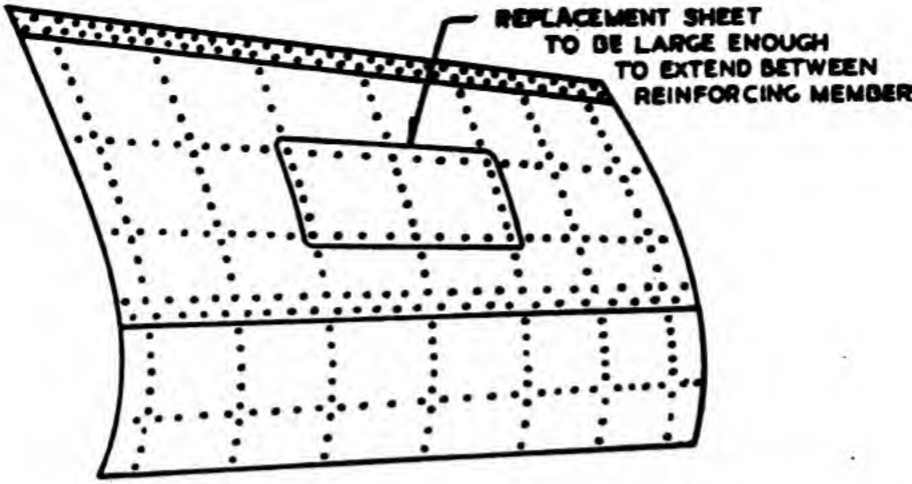


Figure 144.—Size of replacement when entire panel is not removed.

Preparing Replacement Skin

In selecting the material for use in skin replacement, the following factors must be considered:

1. The replaced skin should restore the original strength to the surface since the skin is a structural member of the plane, and as such carries a portion of the stress.
2. The replacement sheet should not be so thick as to add excessive weight to the airplane.
3. It should have the same qualities of corrosion resistance as the original skin.
4. It should be made of a material allowing duplication of the original contour of the section being replaced.

These factors indicate that the material used for replacement must be equivalent to the original skin—that is, 2S must be replaced with 2S, 24S–T with 24S–T, and Alclad with Alclad in order to restore the original strength and durability of the skin.

The size and shape of the skin may be determined in either of two ways. The dimensions can be measured during the inspection, or the old skin can be used as a template for the layout of the sheet and the location of the holes, the latter

method being the more accurate. Regardless of the procedure used, the new sheet must be large enough to replace the damaged area, and may be cut with an allowance of 1 or 2 inches of material outside the rivet holes.

When the new panel has been trimmed to the same size as the original, the size, location, rows, and number of rivets will be the same as on the sheet being replaced. This is a safe practice to follow since these specifications are based on the designer's knowledge of the skin stresses and of the strength required.

If the old sheet is not too badly damaged, it should be flattened out and used as a template. The new sheet, having been cut approximately 1 inch larger than the old, should then be drilled near the center of the new sheet, using the holes in the old sheet as a guide. The sheets are then fastened together with sheet fasteners. The use of sheet metal screws is not recommended since they injure the edges of the rivet holes. The drilling should proceed from the center to the outside of the sheet, inserting sheet fasteners at frequent intervals.

If impossible to use the old sheet as a template, the holes in the new sheet should be drilled from the inside of the fuselage, using the holes in the reinforcing members as guides. Before placing the new sheet on the framework to drill the holes, make certain that the stringers and rings, or bulkheads, are properly alined and flush at the points at which they intersect, otherwise the holes in the new sheet will not be accurately alined. For the same reason, the new sheet should have the same contour as the old before drilling the rivet holes.

Drill holes in the center of the new sheet first, then work to the outside to lessen the danger of objectionable buckles and wrinkles.

It may be necessary to use an angle drill in places where it is impossible to insert a straight drill. In case neither type can be inserted, the new section can be marked carefully with a soft pencil through the holes in the old section. Another method of marking the location of the new holes is to use a sharp pointed instrument such as a transfer or punch

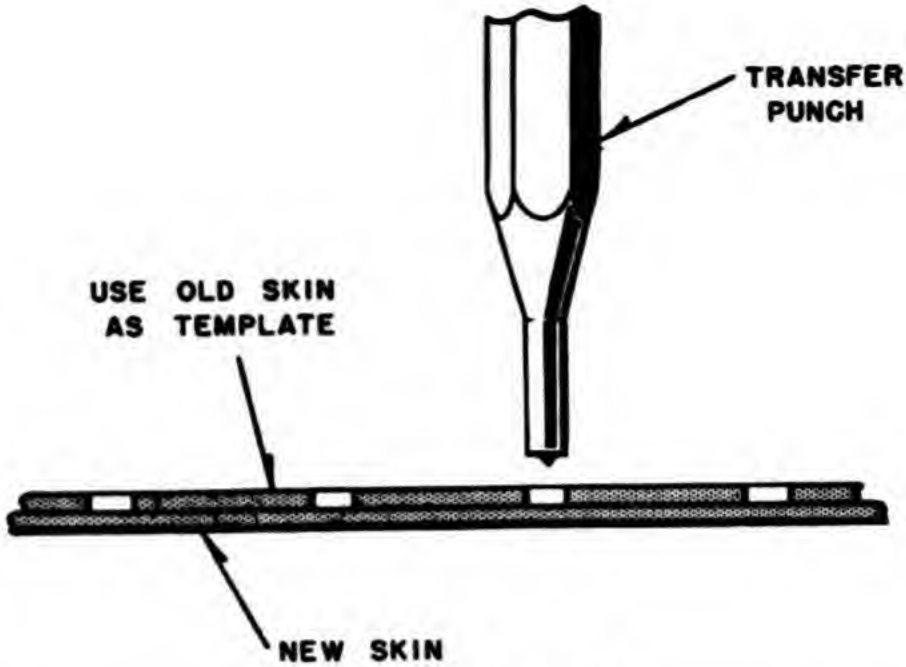


Figure 145.—Transfer punch.

prick, shown in figure 145. Center the instrument in the old hole, then hammer lightly on the outside of the sheet with a mallet. The result should be a mark which will serve to locate the hole in the new sheet.

Still another way to locate the rivet holes without a template is to use a hole finder, similar to the one shown in figure

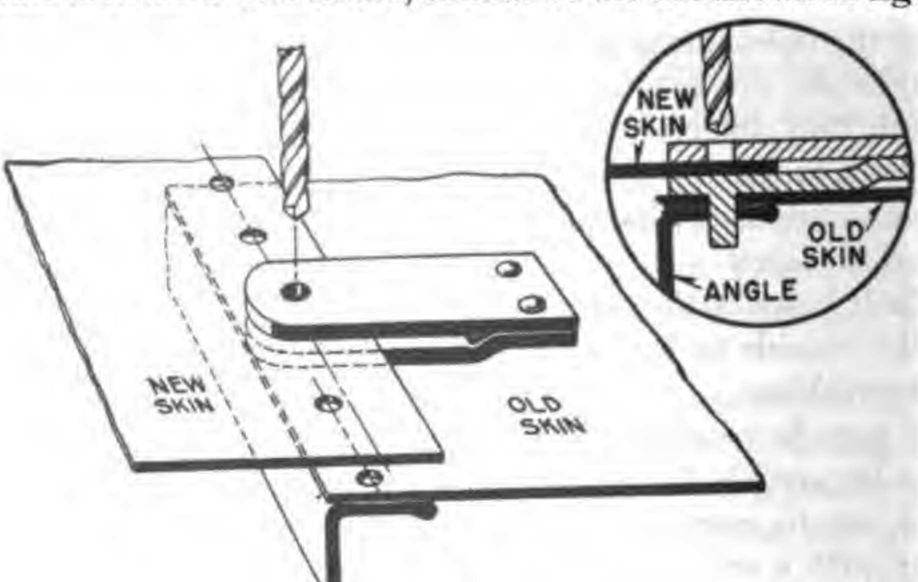


Figure 146.—A hole finder.

146. This device makes it possible to drill holes in the new section of skin which are perfectly alined with holes in the sheet still in place. The hole finder comes in two sections—an upper and a lower part which are bolted together at one end. At the free end of the bottom section of the hole finder is a guide rivet which drops into the old holes in the sheets still in place. The free end of the top section of the hole finder has a hole whose position exactly matches the position of the guide rivet, and through this opening the new hole is drilled. Thus, as the hole finder slides along, the guide rivet drops into an old hole and automatically determines the position of the new hole.

After the holes have been drilled, the edge distance should be marked and the sheet cut to exact size. The corners should be rounded slightly, and all burrs removed from both the holes and the edges to make it possible to hold the sheets tightly together, permitting the rivet heads to seat properly. Apply a coat of zinc chromate to those parts of the sheets that cannot be reached after they are riveted.

Riveting the New Sheet

The selection of a proper type and weight of bucking bar is an important factor in the success of a riveting job. A bucking bar for $\frac{1}{8}$-inch rivets should weigh at least 2 pounds. Bars for larger rivets should be proportionately heavier. A light bar has a tendency to develop a hardened, clinched head because it requires too many blows to upset the head.

Whenever possible, use a straight bar so that its weight can be applied directly in line with the shank of the rivet. Where flanges on ribs or stringers will not permit the use of a straight bar, devise one that will allow pressure to be applied in a straight line with the rivet, such as those in (A) and (B) of figure 147. These bucking bars give much better results than one with a beveled end like that in (C) of figure 147.

Attach the skin to the plane with enough sheet fasteners to hold it firmly in place. The riveting of the replacement panel should begin at the center. Rivet every hole, working

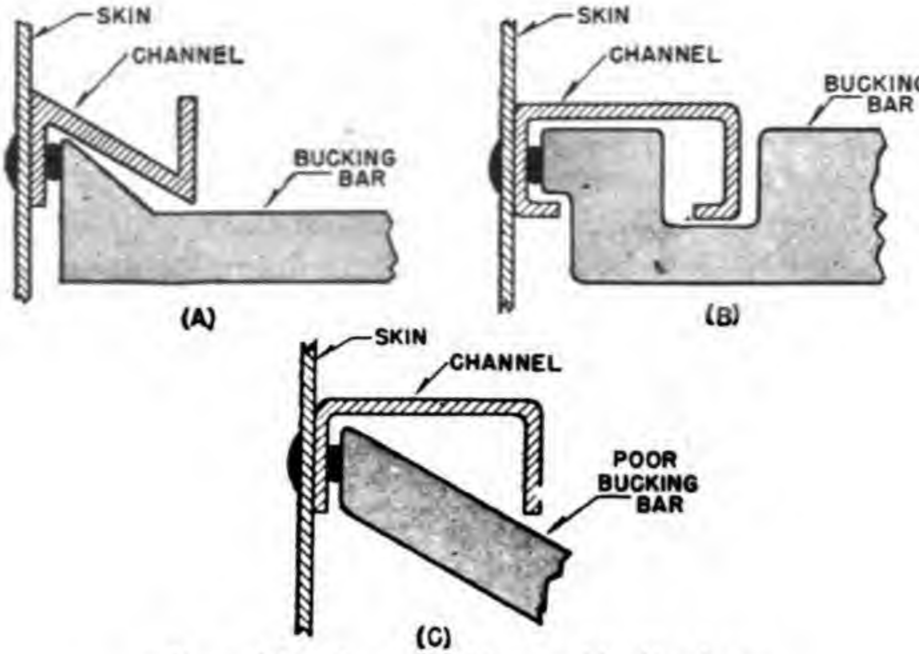


Figure 147.—Correct and incorrect bucking bars.

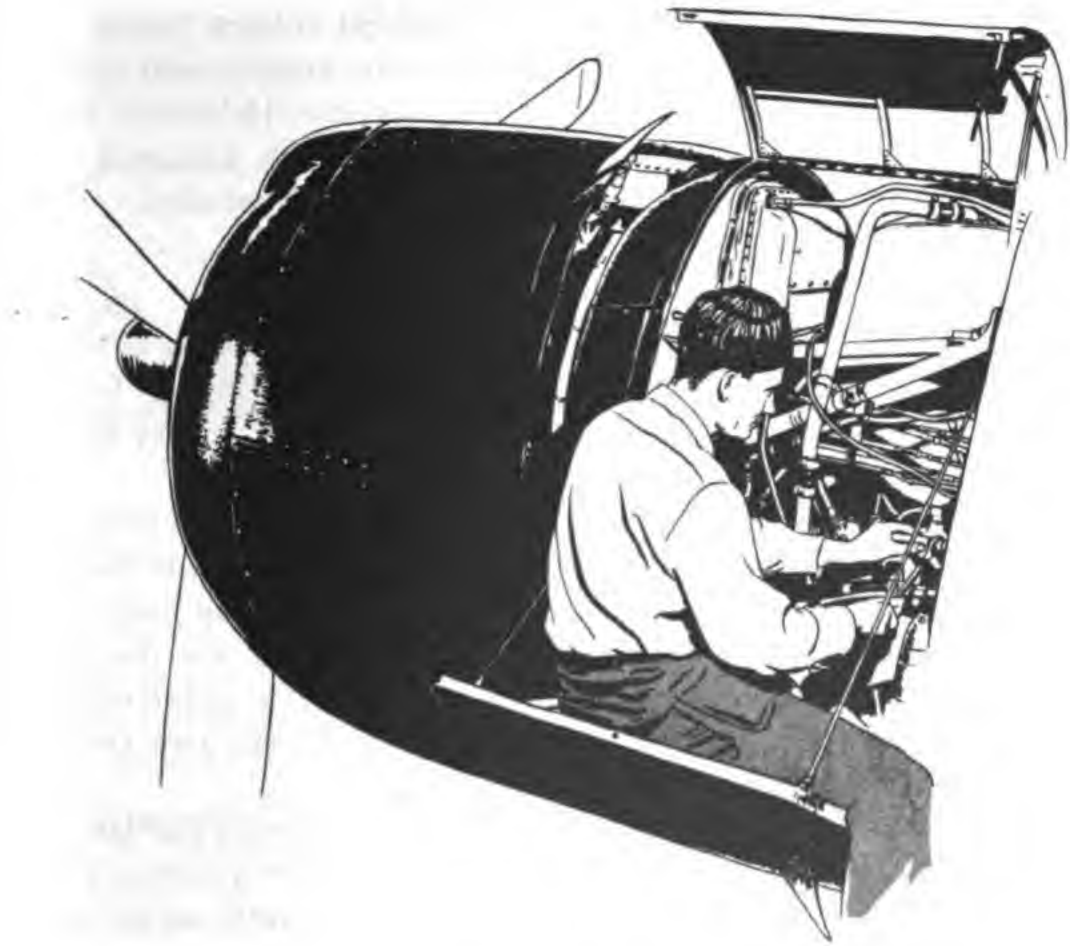
out toward the edges. The remaining holes can be riveted last.

The rivets should have the same heads as the ones being replaced. Exert sufficient pressure on the pneumatic gun to upset the rivets in as few blows as possible in order to avoid strain hardening.

When the riveting has been completed, a coat of zinc-chromate primer can be applied to the inside and outside of all surfaces.

QUIZ

1. What is the prime objective of aircraft repair?
2. Name the two classes of skin repairs.
3. How would you repair a ⅛-inch hole in stressed skin?
4. How many rivets would you use in a patch for a hole in stressed skin that is 1 inch long?
5. What is the maximum length for a filler splice?
6. What type of trailing edges are generally used on smaller fabric covered control surfaces?
7. Why should damaged skin be removed with care?
8. With what alloy would you replace 24S–T?
9. How much should a bucking bar for ⅛-inch rivets weigh?



CHAPTER 8

TUBING MAINTENANCE AND REPAIR

Tubing plays an important role in the operation and construction of the modern airplane. It carries the gasoline and oil for the engine and the hydraulic fluid for the control of flaps, landing gear, and other vital units. Tubing is also used as a shield for electric wiring.

All tubing used in modern aircraft may be classified as either structural or nonstructural tubing. Structural tubing is that used to carry loads—such as frames, struts, and landing gear. Nonstructural tubing is that used in the fuel lines, air lines, hydraulic lines, and similar parts of an airplane.

The hundreds of feet of nonstructural tubing found in aircraft today may be compared with the arteries and veins in the human body. They are, literally, the lifelines of the airplane. If the fuel lines, for example, are damaged or destroyed, the entire plane is put out of commission.

TYPES OF TUBING

There are two types of aircraft metal tubing—rigid and flexible. Rigid tubing has a solid wall of metal made from copper, brass, or aluminum alloy, and is used to carry fuel, oil, or hydraulic fluid.

Flexible tubing is used to join low-pressure lines and to make connections from fuel and oil lines to the engine itself.

Any fuel line directly connected to the engine must be fastened by means of a flexible joint to lessen the danger of failure due to engine vibration. Specially constructed flexible metal tubing and rubber tubing are the two types generally used.

The rubber may be either natural or synthetic, the latter being used wherever gasoline and oil-resistant qualities are necessary. Ordinary rubber deteriorates rapidly when exposed to gasoline or oil. In some metallic flexible tubing, the rubber is used in combination with metal.

Size of Tubing

The size of round rigid tubing is given in two dimensions—the exact outside diameter and the wall thickness, as figure 148 indicates. The diameter is given in fractions of an inch and the wall thickness in thousandths of an inch. The accepted practice is to refer to tubing size by number—$\frac{1}{8}$ inch as No. 2, $\frac{3}{16}$ inch as No. 3, $\frac{1}{4}$ inch as No. 4, etc.—the number being the outside diameter in sixteenths of an inch.

Flexible tubing is measured by the inside diameter because in many cases it must fit over rigid tubing. It can be obtained in various wall thicknesses, the choice of which is determined by the job it will be required to perform. Rubber tubing is not held to as close a tolerance as rigid tubing, and its wall thickness is approximate.

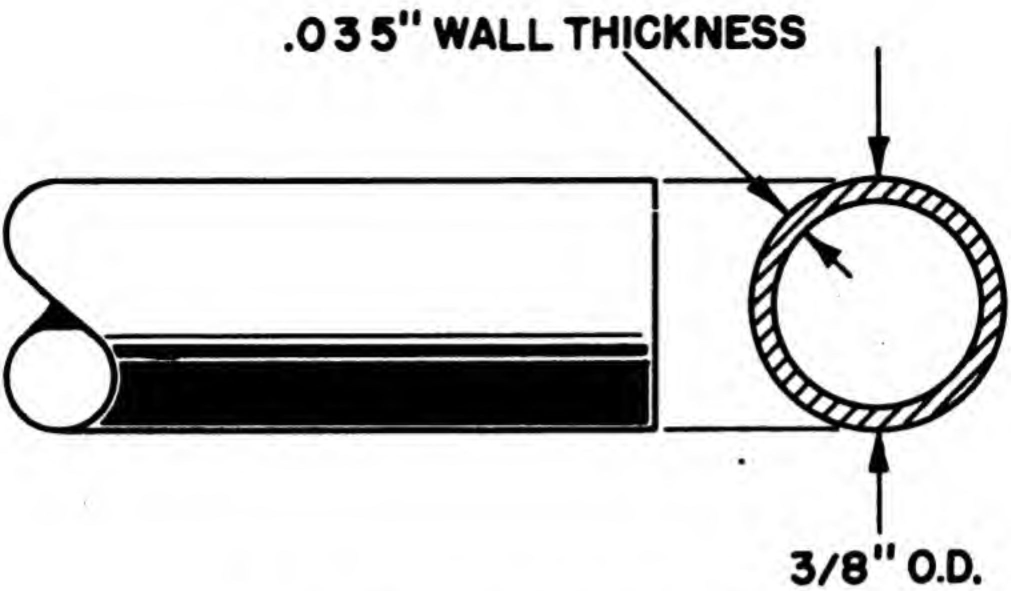


Figure 148.—Typical dimensions of tubing.

TUBING MATERIALS AND USES

Aircraft fuel lines are made from a variety of materials such as aluminum and aluminum alloys, copper, and brass.

The most widely used tubing material in modern airplanes is aluminum and its alloys. Chart 17 lists these alloys and the color marking by which each may be identified. Navy specifications require that the alloy and temper of tubing be marked every 3 to 5 inches.

These identification bands are used to indicate the aluminum alloy of which the tubing is manufactured. They are generally removed or covered up by one or more of the finishing processes required after fabrication, such as anodizing or painting. These bands are not to be confused with the markings used on tubing lines installed in the airplane to identify the particular use for which a line is employed.

52S aluminum tubing has the greatest number of uses in an aircraft. For parts in which strength is not important, such as air-speed indicator lines, 2S and 3S are used.

Aluminum alloys have supplanted copper tubing to a great

Color	System
Red	Fuel.
Yellow	Oil (lubricating).
White	Coolant (water).
Brown	Fire extinguisher.
Light blue	Flotation equipment.
Light green	Oxygen.
Black	Airspeed—pitot pressure.
Light green—black	Airspeed—static pressure.
White—black—white	Coolant (Prestone).
White—light blue	Manifold pressure.
White—light green	Vacuum.
Light blue—light green	Air pressure (compressed).
Light blue—black	Steam.
Light blue—yellow	Purging.
Light blue—brown	Exhaust analyzer.
White—red	Fluid (ice preventive).
Red—black	Vent (closed compartments).
Light blue—yellow—light blue.	Hydraulic pressure oil.

Chart 17.—Color code for tubing lines.

extent because of their lightness and because they do not work-harden and fail as rapidly as copper. Aluminum obtained in the "SO" condition may be fabricated and then installed in the airplane. Copper must be annealed after fabrication and must be reannealed periodically to relieve the strain hardening caused by vibration.

Copper tubing has but one remaining major use on the airplane—it is employed in small lines running from the engine to various instrument installations, because it may be soldered easily. Soldered connections are desirable on instrument lines, because the other types of fittings are not easily installed on these small tubes, and because they are more easily dismantled and reassembled without damage to the tubing or fittings.

Brass also is used for aircraft fittings and tubing, but is limited to a great extent. It is used for some oxygen lines and for parts of some flexible lines.

REPAIR OF TUBING

Repairs to tubing will be determined by the type and use of the damaged tubing. In some cases, repairs will have to be made to aluminum alloy or copper tubing. For the repair of most tubing, the following steps must be performed:

1. Make a template to determine the approximate length of the tubing, and the path it must follow.
2. Cut the tubing and remove the burrs.
3. Bend the tubing to shape.
4. Attach the fittings.
5. Flare the tubing if the flared type of fitting is used.
6. Install the completed section of tubing.

In most repair work, the fuel lines are bent and fitted on the job without an accurate drawing of the original pieces. The chief objectives are to follow the same path as the original piece, and to make certain that the replacement is alined with the fittings to which the tubing is to be attached. The only way to determine the path the tubing is to follow, and its approximate length, is to make a template of soft brass or aluminum rod, about $\frac{3}{16}$ inch in diameter. If no such material is available, discarded tubing $\frac{1}{4}$ inch in diameter, or less, may be used. The old tubing being replaced may also be used as a guide.

TUBE CUTTING

Tubing for the repair is cut to approximate length before bending, and is cut to exact length after it has been bent and checked. By this is meant that it is alined with the fittings to which it is to be attached. TUBING MUST BE CUT EXACTLY SQUARE, and it must be perfectly burred if the succeeding operations are to be properly performed. There are two methods used to cut tubing. One is with a regular pipe or tube cutter, which resembles a pocket-size pipe cutter and which automatically makes a square cut. This procedure is

illustrated in figure 149. The other method is to use an ordinary hacksaw.

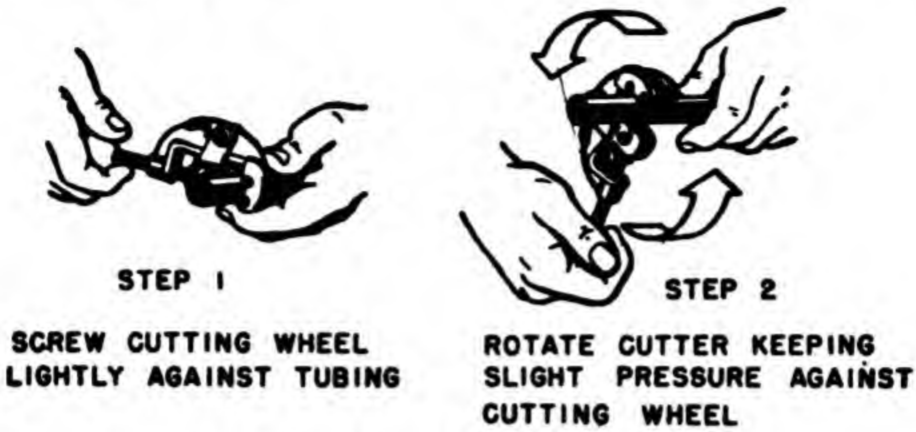


Figure 149.—Cutting tubing with a tube cutter.

In cutting with a hacksaw, particular attention must be paid to the method of holding the tubing and to the blade used in making the cut. Tubing can be held in a V-block, or a block grooved to fit the tubing, as demonstrated in figure 150. Hacksaw blades for tube cutting should have 32 teeth to the inch.

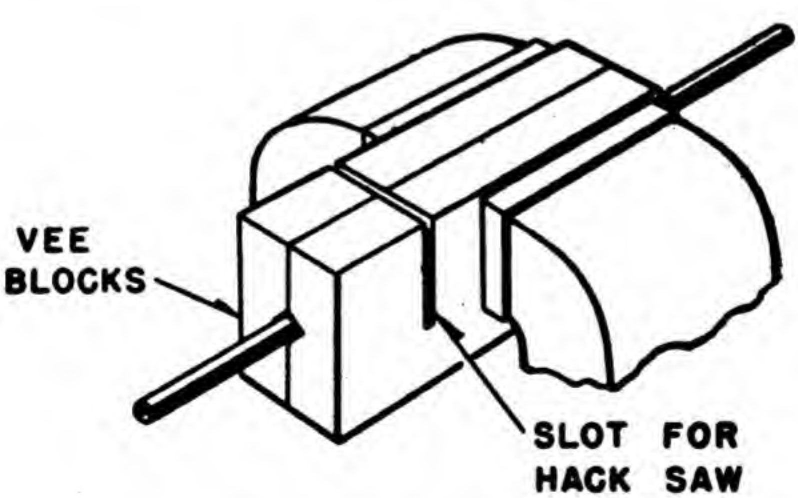


Figure 150.—Vee blocks for holding tubing.

Burring

When the tube has been filed square, it must be burred inside and out to prevent a leaky joint or split tube. Inside burs can be removed with a machinist's scraper or a pocket knife as in (A) of figure 151. Outside burrs can be easily removed with a flat file as shown in (B). Do not round the corners excessively.

Cleaning

Remove all filings, chips, burrs, and grit from the inside of the tube to avoid split flares and pock marks on the fitting seats. If available, compressed air blown through the tube provides the best method of cleaning out any foreign particles.

Occasionally dents will be found in tubing. These can also be removed—if they are less than 20 percent of the tube diameter—by running a die or bulletlike tool through the tube.

When aluminum tubes are to be anodized for greater resistance to corrosion, it is best to treat the tube after all flaring and bending has been completed.

(A)

(B)

Figure 151.—Burring inside and outside.

Tube material	Outside diameter (inch) inclusive	Wall thickness (inch) inclusive	Minimum bend radius — O. D. × factor below — Structural use	Minimum bend radius — O. D. × factor below — Piping fluids	Method of bending (see legend below) — No filling	Fill with — Sand — Coarse	Fill with — Sand — Fine	Fill with — Resin	Fill with — Spec. 11078 or other low temperature fusing alloy	Heat treatment — Before bending	Heat treatment — After bending
Aluminum and 52 aluminum alloy.	0.25–1.50	0.032–.051		3	#3		#1 or #2		#4 or #5 / #1 or #2		
	1.625–3.000	.057		3			#1 or #2				
17 and 24 aluminum alloy.	.25–2.00	.022–.065	6	4	#3		#1 or #2		#4 or #5 / #1 or #2	Anneal or heat treat.	Heat treat.
	2.25–3.75	.065–.120	6	4			#1 or #2			Anneal or heat treat.	Heat treat.
Brass			5	4	#3			#1 or #2	#1 or #2		Anneal.
Copper	.125–1.125	.035–.049	3	3	#3		#1 or #2	#1 or #2			Anneal.
Copper, silicon, bronze			3	3	#3		#1 or #2	#1 or #2			Anneal.
1025 steel	.125–1.50	.028–.065	5	3	#5	#6				Torch	Normalize.
	1.625–4.000	.065	5	3		#6				Torch	Normalize.
X-4130 steel	.188–1.500	.022–.065	5	3	#5	#6				Torch	As required.
	1.625–2.750	.049–.120	5	3		#6				Torch	As required.
Corrosion resistant steel.	Minimum bend radius depends on composition, condition, and bending equipment.								#2		Anneal.

Chart 18.—Bend radii of aircraft alloy tubing.

After the tubing is cut, it is bent to the shape of the template. Tubing may be bent by hand with a wire tube bender, in V-blocks, with a mechanical hand tube bender, over a radius block, or in a production bending machine. The tubing must be bent so that it is neither buckled nor flattened.

Bending by Hand

Small sizes of tubing up to ¼ inch—such as is used for air speed lines—may be bent by hand, as shown in figure 152, if the curve is bent gradually. In hand bending, the radius must be greater than when using mechanical benders to avoid buckling or flattening the tubing.

Figure 152.—Hand bending of tubing.

Chart 18 illustrates the proper radius of mechanical bending of each type of tubing used in a plane.

Bending With Wire Tube Bender

Medium-size tubes—from ¼ to ⅝ inch—such as are used for fuel lines and small oil lines, can be bent successfully with a coil wire tube bender of the correct size. This in-

strument is shown in figure 153. The bender is slipped over the tube where the bend is to be made and the desired curve formed by hand, with or without the use of a bending block. After the bend is made, the coil is removed by pulling and twisting against the spiral to avoid unwinding the spring and scarring the tubing.

Figure 153.—Wire tube bender.

Bending in V-Blocks

Almost any size of tubing can be bent with V-blocks. Tubing $\frac{1}{2}$ inch in diameter, and over, must be bent with the aid of a filler material. The use of fillers will be discussed in subsequent paragraphs. To use the V-blocks, clamp them in the vise with the tubing between them, and bend the tube by hand. This method of holding the tubing is identical to that used when cutting with the hacksaw.

Bending With Hand Tube Bender

The hand tube bender, shown in figure 154, may be used to bend the smaller sizes of tubing. Each size of tubing requires a different size of bender. The hand tube bender is made up of three parts—a radius block, a clamp, and a forming bar.

Care must be taken in bending tubing to prevent its slipping in the clamp, as the clamp fits loosely on most benders. A piece of emery cloth wrapped around the tubing underneath the clamp will eliminate slipping. The larger sizes of tubing will require the use of filler material to prevent wrinkling or buckling.

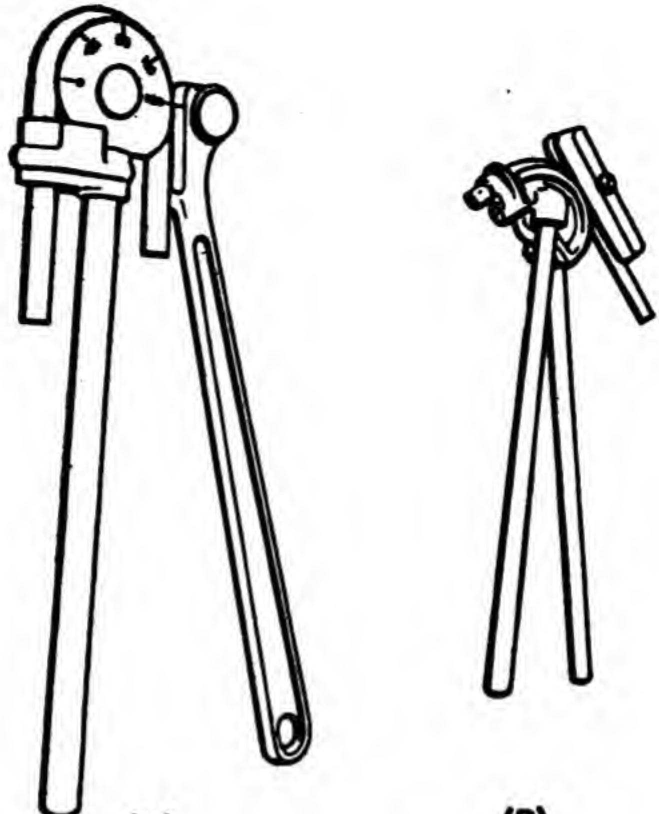


Figure 154.—Hand tube bender.

Bending With Radius Blocks

Bending with radius blocks is a common method of bending tubing, as may be seen in figure 155. Sizes over ½ inch require the use of a filler material. The radius of the bend should be carried about 15° past the desired bend angle to allow for spring-back. A groove to fit the tubing should be cut in the block. A small clamping block, grooved to fit the tubing, is used to hold the tubing in place.

Figure 155.—Radius block.

Bending With Production Tube Bender

The production tube bender is used in O & R and maintenance shops where a considerable amount of tubing is bent. The bending is accomplished with the use of a mandrel inside the tubing in place of filler materials.

FILLER MATERIALS

The larger sizes of tubing must be filled with some materials to prevent flattening the outside and buckling the inside. Filler materials which are commonly used include sand, resin, and special bending alloys with a very low melting point.

Sand is the most commonly used filler. For best results, it should be fine and dry. To fill the tubing, one end is plugged tightly with a piece of soft wood, or if the tubing has been cut long enough, the end of the tubing can be flattened, bent over, and flattened again, as shown in figure 156. As the sand is poured in through a funnel, the tubing should be tapped with a stick to firmly pack the sand into place. When the tubing has been filled, plug or flatten the other end.

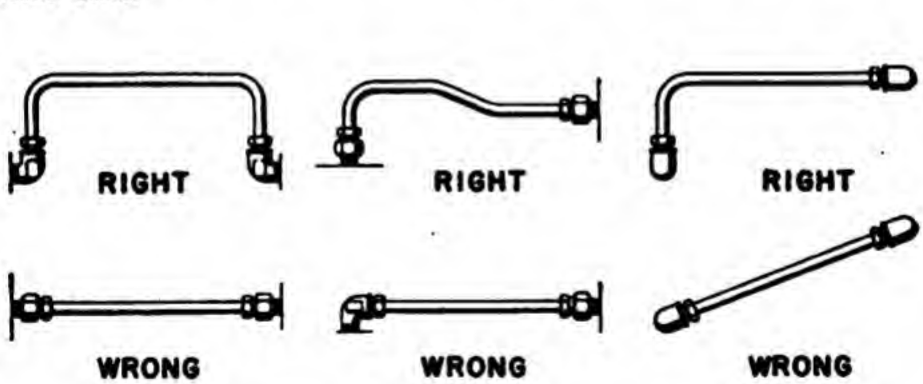


Figure 156.—Repairing tubing to receive filler.

Special alloys are used as a filler when bending the larger sizes of aluminum alloy and copper tubing because they expand slightly when cooled and thus make a tight fit in the tube. They are especially useful for complicated bends. Trade names for some of these alloys are CERROBEND, BEND-ALLOY, and TUBALLOY. Although they are more expensive

than sand or resin, they may, if heated properly, be used over and over indefinitely. Heating with a torch or over an open flame is likely to ruin these alloys, and therefore they should be heated in a ladle in boiling water. Copper tubing should be protected from possible tinning of the inside by a light coat of oil.

When one end of the tube is plugged, it is filled with boiling water. Melted alloy is then poured into the tube until all the water is displaced. By thus preheating the tubing, the alloy will remain in a liquid form while the tube is being filled.

When filled, the tubing is held under cold running water to chill the alloy. This alloy bends easily when cold, but has a tendency to break when warm or when bent rapidly. Tubing should, therefore, be bent slowly, and only when the alloy is fully cooled. The tubing may be bent with the aid of the bending apparatus just described. When the bending is completed, the alloy is removed by heating the tube in steam or boiling water.

Resin is used in much the same manner as the special bending alloys. One end of the tube is plugged and the resin is melted in some type of ladle to facilitate pouring. The tube should be preheated to prevent the resin from hardening before it reaches the plugged end, otherwise air pockets will be formed which will cause the tube to flatten at that point when it is bent. The resin should cool to room temperature.

One precaution should be observed when removing the resin. The heat must be applied at the open end of the tube first and moved along as the resin melts and runs out. If this is not done, an explosion may result from the resin melting and expanding while being confined by solid resin.

ANNEALING

Both copper and aluminum alloy tubing must be in the dead soft condition before fabricating. While it will generally be in that condition when received, at times the tubing will prove too hard to bend and will require annealing. Copper must always be annealed after bending and before installation.

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The chief difficulty encountered in shop annealing will be in determining when the annealing temperature has been reached. Aluminum alloy can be heated by a gasoline blow torch or a welding torch until it will char a soft-wood splinter. Another way to check for temperature is to apply a coating of carbon with a carbonizing flame of the acetylene torch, then to heat the tubing with a neutral flame until all the carbon is burned off.

Copper must be heated to a temperature of approximately 600° F. and annealing will be almost immediate. Rainbow colors appearing on the surface of the copper will indicate that the temperature has been reached.

To remove internal and external surface scale, copper tubing at the annealing temperature can be quickly immersed in water and subsequently blown out with compressed air.

ARRANGEMENT OF TUBE LINES

Avoid laying out tubes from point to point in a straight line, as it is practically impossible to flare the tubing to the exact length and prevent the flare from being pulled out when the fitting is tightened. A straight tube provides no opportunity for expansion and contraction due to temperature changes. Figure 157 illustrates the right and wrong methods of laying out tubing.

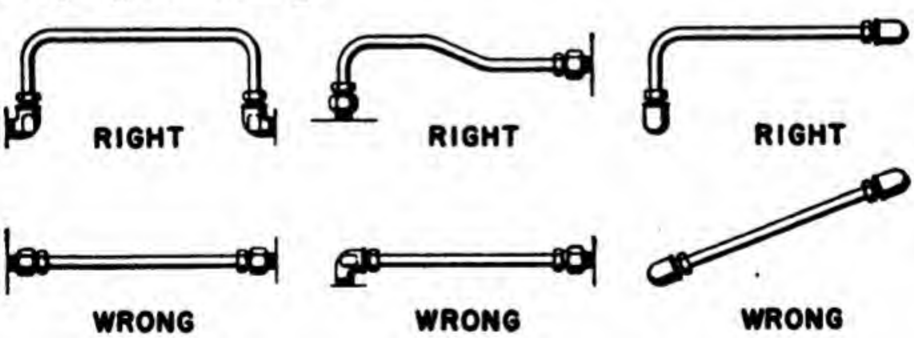


Figure 157.—Right and wrong methods of installing tubing and fittings.

LOCATING BENDS IN TUBES

To avoid difficulty in flaring and assembling, a sufficient length of straight tube must be allowed from the end of the

tube to the start of the bend. Allow at least 2½ times the length of the nut for the two-piece inside thread fitting, and at least 1½ times the length of the sleeve for the three-piece outside thread fitting. Figure 158 illustrates the method of locating bends in tubes when standard or triple-type fittings are used.

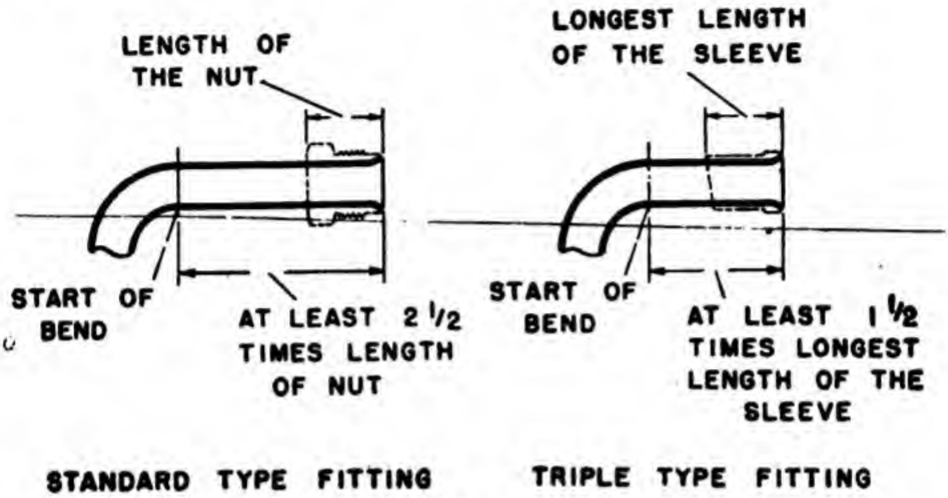


Figure 158.—Locating bends in tubes.

ATTACHING TUBE FITTINGS

After the tubing has been bent, it is ready for the fittings. A tube fitting is a small metal part which is used to connect pieces of tubing to tanks, carburetors, or to other pieces of tubing. These fittings are obtainable in many shapes, each being designed for a particular function. Such fittings are referred to as unions, T's, couplings, elbows, etc.

Fittings are attached to the lines by soldering or flaring. The flaring method is used for most fuel, oil, and hydraulic lines, while soldered connections are used on some copper lines. One form of flared fitting is the bulkhead fitting which has four parts—a body which runs through the bulkhead, a nut to secure it, and a nut to fasten each tube to the body.

There are two types of flared fittings—the standard two-part fitting and the triple-tube fitting, shown in figure 160. The triple-tube type is used where it is necessary to make connections in close quarters, since the tubing extends a much shorter distance into the fitting, and hence can be

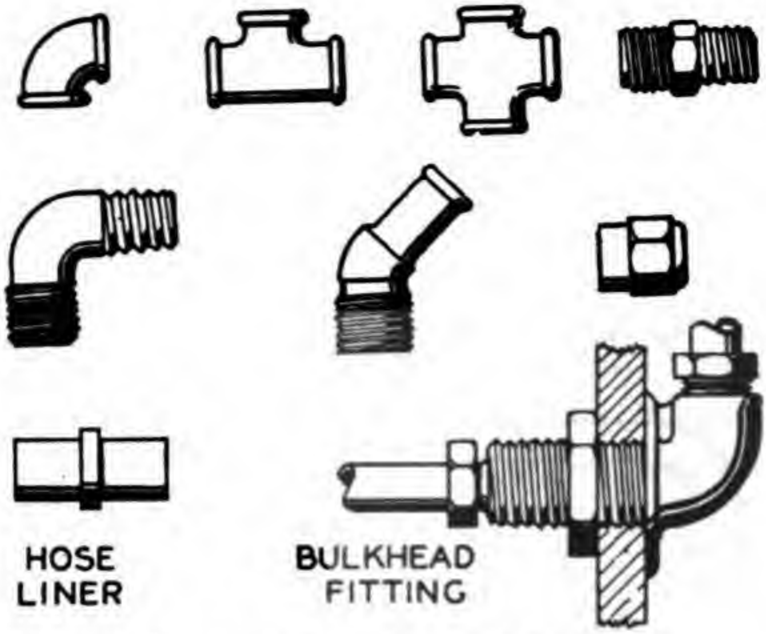


Figure 159.—Several types of fittings.

readily removed. It is better for use in hydraulic systems because it supports the tube at the point of attachment.

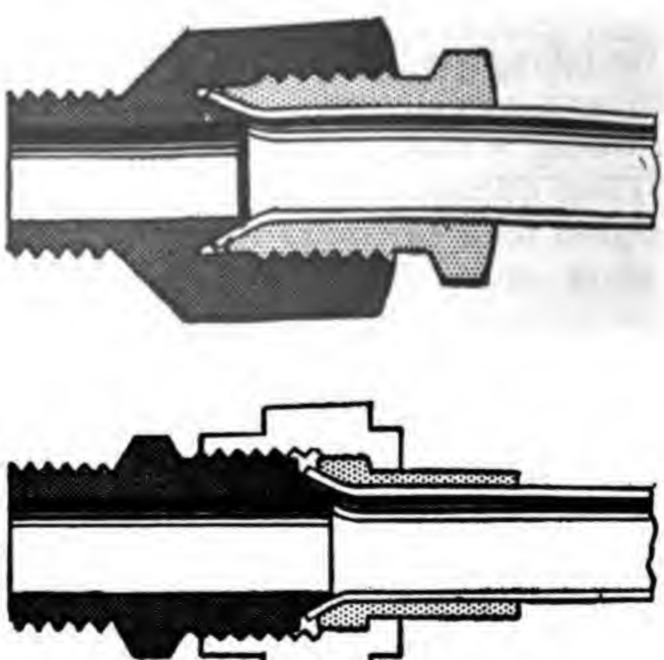


Figure 160.—Standard and triple-tube fittings.

A fitting will have two or more ends to which connections will be made. All of the ends may have pipe threads to make connections to carburetor, gas tank, accessory, or another fitting, or they may have machine threads to receive nuts for coupling.

Chart 19 gives the standard outside diameter of the most common tubing sizes for fuel and oil lines with the corresponding size of the tube fittings required. This table refers only to the pipe thread—the diameters of the sleeves and nuts must be such as to fit the tubing properly. Any fittings with machine threads will be dimensioned by the diameter of the tubing. Any pipe thread connection will be indicated by the corresponding pipe thread.

Tubing diameter	Pipe thread size
1/8	1/8
3/16	1/8
1/4	1/8
5/16	1/8
3/8	1/4
1/2	3/8
5/8	1/2
3/4	3/4
7/8	3/4
1	1
1 1/4	1

Chart 19.—Tubing sizes.

Attaching Flared Fittings

The nut and sleeve should be placed over the end of the tubing before beginning the flare, as they obviously will not slide on over the completed flare.

Flaring, or belling as it is sometimes called, is the stretching of the end of the tubing to match the fitting which

holds it in place, as shown in figure 161. There are several flaring tools used for this hand process—the ball type, the hammer type, and the combination type.

Figure 161.—A flare.

Figure 161.—A flare.

Standard and Triple Ball-Type Flaring Tool

The standard type tool is used for a two-piece fitting, and the triple ball type for a three-piece fitting. Both are recommended for thin-wall, standard weight, soft copper or aluminum tube only, with an outside diameter of $\frac{3}{8}$ to $\frac{3}{4}$ inch. The following instructions apply to both types.

Slip the B nut or the triple nut and sleeve over the end of the tube to protrude about $\frac{1}{16}$ inch for a $\frac{1}{2}$-inch outside diameter tube, and more or less depending on the size of the tube. This step is illustrated in (A) and (B) of figure 162. The nut and tube are then gripped in a vise or held in the hand for flaring.

(A) (B) (C)

Figure 162.—Use of ball-type flaring tool.

Insert the flaring tool to the tube shoulder and rotate, pressing outward and downward until the flare fits the nut. The best results are obtained with a slow circular wiping motion

and a firm even pressure to hold the tool neck against the tube, as shown in (C).

After flaring, thread the tool nut to the tube nut to even out the flare. When using the triple-type flaring tool, screw the tube nut to the threaded portion of the tool. Excessive wrench pressure is not necessary to insure a smooth flare.

Combination Hammer-Type Flaring Tool

The combination hammer-type flaring tool is used on thin-wall, soft-annealed copper or aluminum tubing only, with outside diameters from $\frac{1}{8}$ to $\frac{1}{2}$ inch. It will flare tubing for either the two- or three-piece fittings.

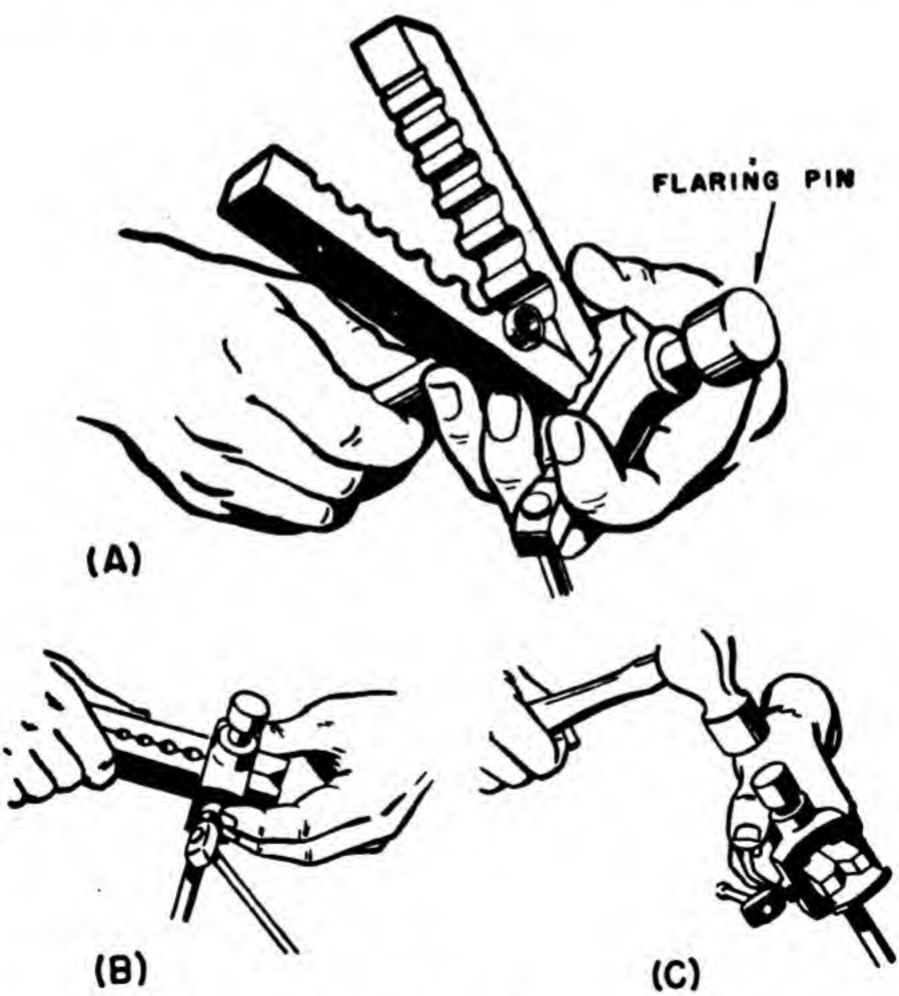


Figure 163.—Use of combination hammer-type flaring tool.

Slide the flaring pin yoke as far back as it will go and spread the block jaws in order to insert the tube, as shown in (A) of figure 163. A spring catch holds the flaring pin raised while sliding the yoke.

The tube should be approximately flush with the top of the flaring block jaws. Slide the yoke over the tube and clamp it tightly in place with the adjusting screws, as shown in (B).

Lower the flaring pin to the tube either by hand or with a slight hammer tap. Start the flare with light hammer blows and continue until completed. Section (C) illustrates this step. To remove the tube, raise the flaring pin, loosen the yoke and slide it back to its original position.

Standard of Triple Hammer-Type Flaring Tool

These hammer-type tools are designed for copper or aluminum tubing of moderately heavy wall thicknesses with outside wall diameters from 3/8 inch to 2 inches. The standard type is used on two-piece fittings, and the triple-type on either style.

To use this tool, screw the tube nut and flaring tool together until only the last thread remains visible.

Insert the tube as far as it will go. Grasp the tube beneath the tool and flare it with a number of light hammer blows. The first few blows, especially, should not be too hard because the nut may become too tight on the tube.

Figure 164.—Using standard or triple-hammer flaring tool.

After the flare has been well started, screw the nut and flaring tool tightly together, then grasp the tool—rather than

the tube—and flare until completed. With the standard tool, the progress of the flare can be observed through the cutaway, whereas the triple-type must be unscrewed from the tube. If the flare is not completed, replace the tube and finish it.

CORRECT FORM AND DIMENSIONS OF FLARES

Although incorrectly formed flares may seem to be satisfactory and pass initial pressure tests, they cannot be depended upon for continuous service. To insure proper seating, all flares should conform to accepted general requirements as determined by the type of fitting to be used for coupling the tube.

Correct diameters for the standard and triple-type fittings are shown in figure 165. Incorrect flares are shown in figure 166.

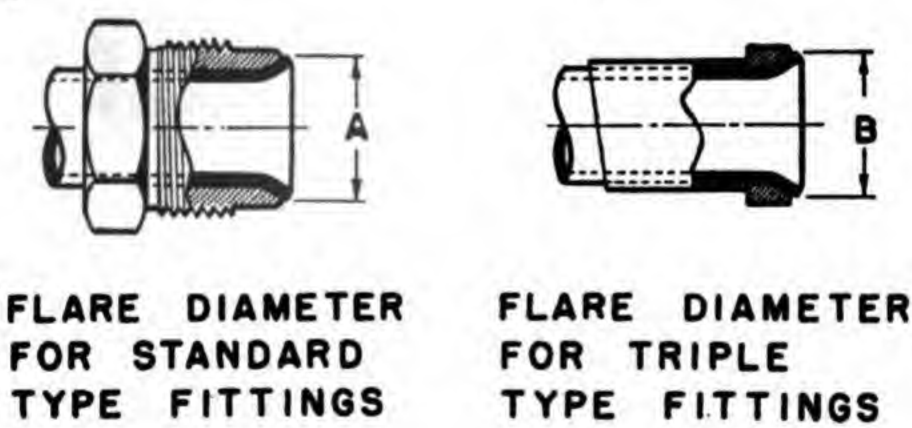


Figure 165.—Correct diameter of flares for standard and triple-type fittings.

Figure 166.—Bad flares.

For quickly checking flare diameter, gages with holes for measuring go and no-go flare sizes are available, as shown in figure 167.

The flare angle of the tube should be the same as the flare angle of the fitting. Incomplete flares cannot be depended upon to draw down properly on the fittings seats.

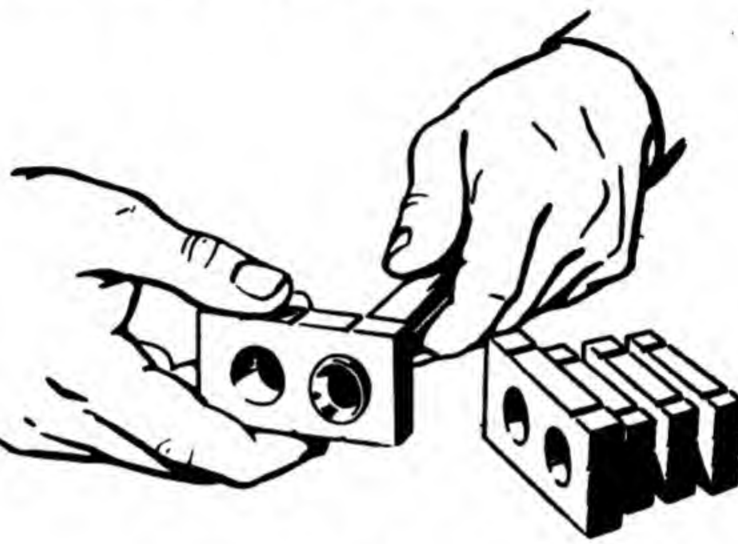


Figure 167.—Go and no-go gage.

In such cases, the nut tends to climb up on the flare so that there is very little grip on the tube after the fitting is assembled. For best results, complete all flares with the flaring tool to the proper angle.

Flares must be square and concentric with the tube and tube nut in order to seat properly. Flares may be out of square and eccentric because the tube has not been cut off square or because the flare has been unevenly formed in the flaring tool.

Uneven flares are not usually aligned with the fitting seats, and require greater wrench pressure to draw tight. If the flare is large, the elongated side will bottom in the fitting to prevent normal seating, or it will stick in the fitting threads. If the flare is relatively small, the shorter side will not be gripped securely between the fitting seats, and leakage may develop.

The radius at the base of the flare should coincide with that on the tube nut. Otherwise, difficulty in obtaining a proper seat may be experienced. If the tube has been flared into the nut or sleeve of the fitting, the radius will automatically be correct. Flaring blocks are originally provided with the correct radius, and this radius will be obtained if correct flaring pins are used. Makeshift wooden flaring blocks quickly flatten out at this point and should not be used.

ASSEMBLING THE CONNECTION

Flares on thin, soft-annealed copper and aluminum tubes can usually be smoothed out to their proper form directly in the fitting during assembly. With the heavier and harder tubes, it is preferable to draw the flare into the perfect seating form by first assembling it with a hardened seating tool.

With the two-piece fitting, the nut should turn freely on the tube after it has been flared. If the nut sticks, free it before assembling the joint by tapping it on the flats of the hex with a hammer.

With the three-piece fitting, it is preferable to allow the sleeve to remain tight on the tube, provided it is properly in place against the flare. If the sleeve is tight, there will be less chance for it to turn on the tube and wipe the flare surface.

A few drops of oil on the threads will aid in assembling the nut to the fitting. If the fitting parts are aluminum alloy, the threads must be lubricated with a suitable anti-seize compound.

Before assembling the joint, check to see that the tube is in proper alignment with the fitting and that it does not have to be sprung into position because of improper bending. Figure 168 shows right and wrong alignment of tubing and fitting.

Thread the parts together by hand as far as possible, then loosen the nut and jiggle the tube to make certain that the flare is down on the seat. Using smooth-jaw wrenches—one on the nut and one on the fitting—draw the joint tight. Avoid excessive wrench pressure when pulling down soft aluminum all

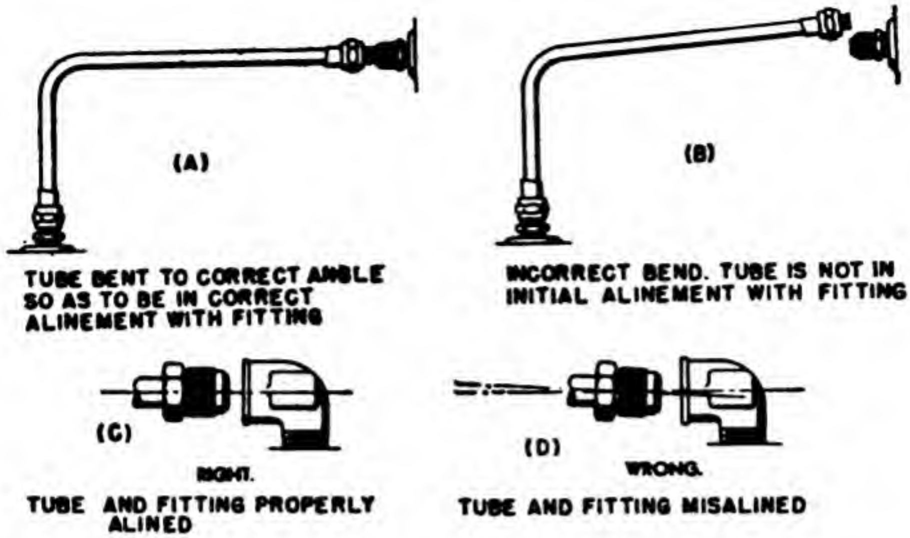


Figure 168.—Correct and incorrect alignment.

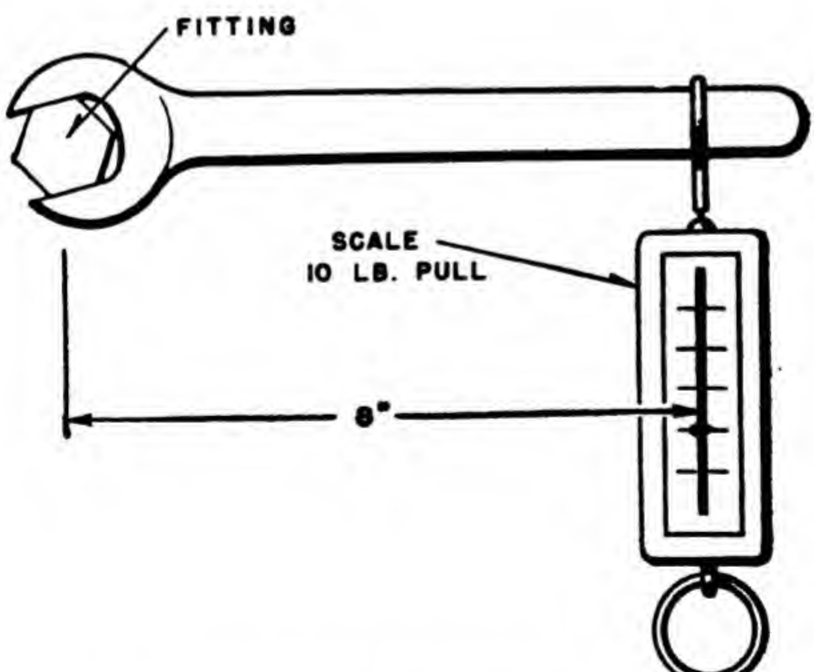


Figure 169.—How to estimate torque pressure.

There is equal danger in overtightening as in undertightening a fitting. If a torque wrench is not available, the device shown in figure 169 can be used to ascertain the correct torque pressure.

ATTACHING SOLDERED FITTINGS

Soldered fittings can be used only on copper. Since the annealing temperature of copper is higher than that of soft solder, the tubing should be silver soldered. The soldered fitting uses a union tail which is slipped on with the nut. The tail is soldered flush with the end of the tubing, after which the fitting is screwed together like any of the other types. Figure 170 illustrates a soldered fitting.

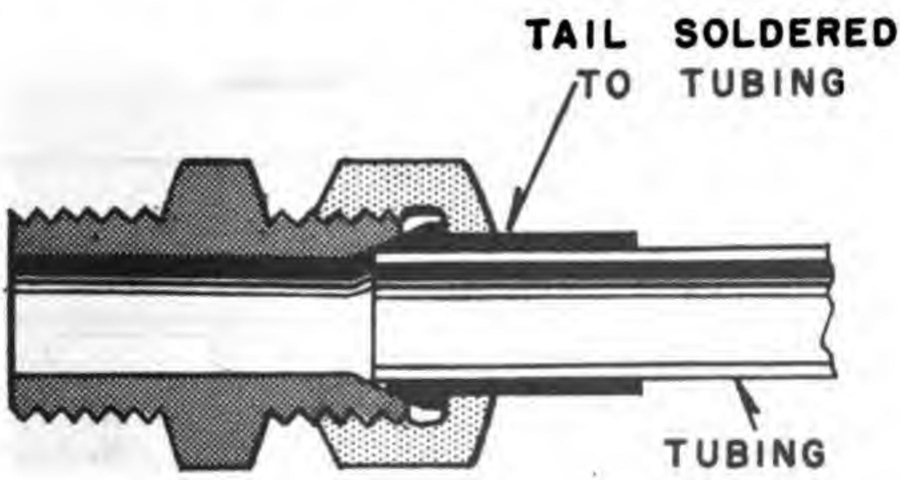


Figure 170.—A soldered fitting.

ATTACHING FLEXIBLE FITTINGS

Any fuel line which is directly connected to the engine must be equipped with a flexible joint, usually a rubber hose fastened with hose clamps to the ends of the tubing to lessen the danger of failure. Flexible metallic tubing is best repaired by replacing damaged sections with pieces of the proper length and of special construction with fittings attached by the manufacturer. Standard fittings cannot be used.

Fittings made to be used with hose connections are usually beaded at the unthreaded end to make a tight fit. A bead is a raised portion at the end of the tube which helps to hold the hose in place and renders the joint watertight by being pressed into the rubber.

Making a joint by means of a hose connection is a simple job. The ends of the tubing are cut absolutely square. After the burrs have been removed, the ends are beaded with a tool such as that shown in figure 171. The bead size should be standard, as indicated in chart 20. The connecting piece of hose should be about 3 inches in length, and the ends of the tubing should be located approximately in the center of the piece of hose and about 1/16 to 1/8 inch apart. The hose clamps should be placed directly behind the beads and securely tightened. A hose liner must be used on the inside of the flexible hose when the connections are made to keep the fuel from coming in contact with the hose.

Tube O. D. (D)	Bead height (A)	R rad. (max.)	S rad. (max.)
	+0.003		
1/4	.038	1/8	1/16
3/8	.038	1/8	1/16
1/2	.038	1/8	1/16
5/8	.038	1/8	1/16
3/4	.038	1/8	1/16
1	.062	5/32	3/32
1 1/4	.062	5/32	3/32
1 1/2	.072	5/32	3/32
1 3/4	.072	5/32	3/32
2	.082	5/32	3/32
2 1/2	.082	5/32	3/32
3	.082	5/32	3/32

Chart 20.—Standard dimensions for hose connections.

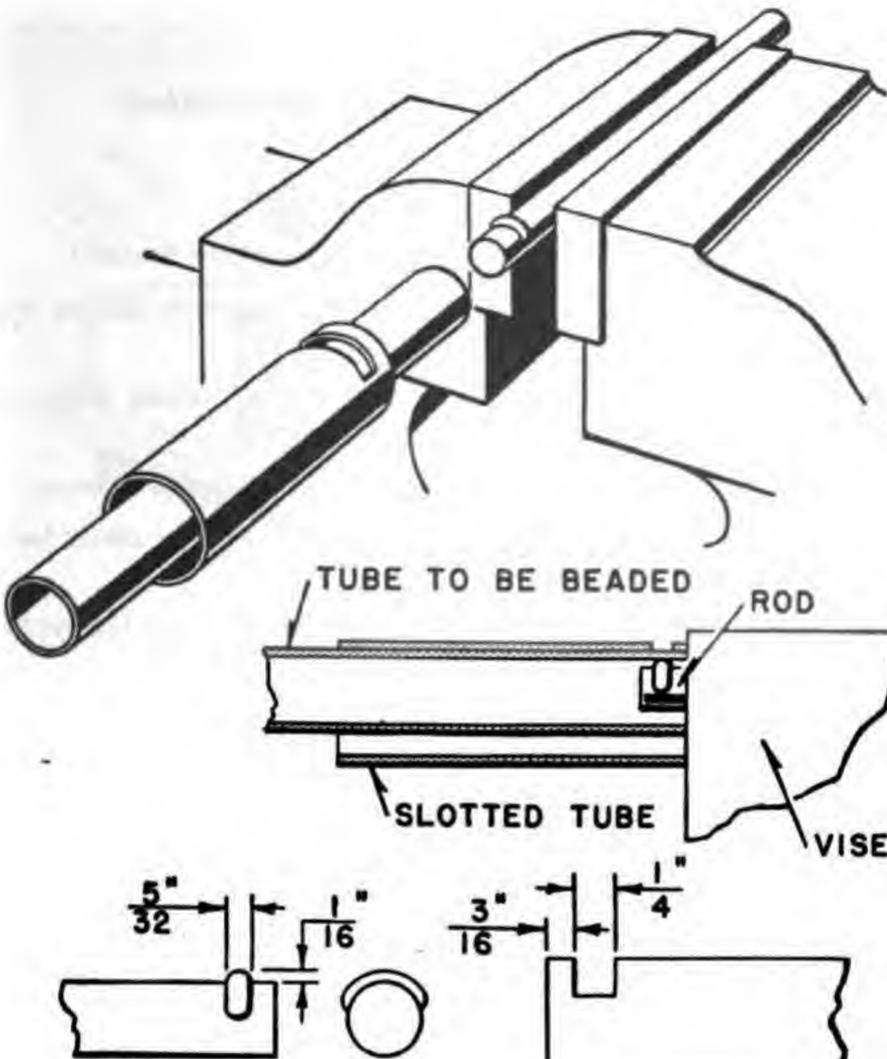


Figure 171.—Beading tool.

IDENTIFICATION

If the tubing lines were unmarked, it would be practically impossible to identify them. For this reason, a color code is used by the Navy to designate the various lines. This color code is shown in chart 17. For example, red indicates that the line carries fuel. Each stripe is approximately ½ inch wide. A single color or a combination of colors is used.

QUIZ

1. How may tubing used in modern aircraft be classified?
2. What aircraft tubing must be flexible?
3. How is flexible tubing measured?
4. Why must the ends of tubing be cut square before flaring?
5. Why has aluminum alloy largely replaced copper in tubing material?
6. What is the general rule for quenching copper tubing after annealing?
7. What color band is used on fuel lines? On lubricating lines?
8. On a hacksaw blade used for cutting rigid tubing how many teeth should there be to the inch?
9. What is the diameter bend radius for a copper line 1⅛ inches in diameter?
10. How should tube bending filler alloys be heated?
11. What is the advantage of the triplet tube type of fitting?
12. Which aluminum alloy is most widely used for tubing?

CHAPTER 9

RUBBERIZED EQUIPMENT MAINTENANCE

RUBBER MATERIAL STOWAGE

Rubber is tough and rugged, yet seriously affected by certain elements, atmospheric conditions, and inadequate stowage facilities.

The essentials of general rubber stowage require moderate temperature, darkness, elimination of excess moisture, cleanliness, avoidance of sparking electrical apparatus, and still or dead air.

Temperature has varying effects on certain types of rubber and their state of cure, and is also a vital part of most vulcanizing processes. This is the reason for stowing all uncured rubber stocks and cements under comparatively low temperatures, but above freezing. Temperatures for these materials should be maintained between 40° to 50° F. for best results.

Direct or reflected sunlight has effects on some rubbers similar to the effects of heat. A minimum use of artificial light from incandescent lamps is most adaptable for lighting requirements of rubber stowage.

Moisture or high humidity in warm climates is responsible for the growth of approximately 800 different types of mildew. These mildews under certain conditions are harmful to some rubbers and most rubberized fabrics. Where suitable low temperatures are not available, the use of incandescent lamps may be required to dry the stowage atmosphere, although a sacrifice in temperature is necessary. Some oil-resistant rubber equipment may be coated with light engine oil to prevent fungus or mildew growth.

Cleanliness is a requirement of any stowage, since there are endless forms of foreign materials, commonly considered dirt, which are injurious to rubber. Some of these are oils, greases, acids, and alkali, all of which may be contained in common dirt. Any or all of these substances, when accumulated on rubber surfaces, either cause direct chemical breakdown or have a tendency to reduce the bonding effects of cemented or vulcanized surfaces.

Ozone, a form of oxygen found in the atmosphere, is produced excessively from electric sparks. Its oxidizing qualities are much greater than oxygen itself. Ozone causes rubber to crack much quicker than normal atmospheric oxidation. To eliminate ozone cracking, or excess oxidation, all electrical apparatus of a sparking nature should be placed away from rubber stowage rooms.

Oxidation of rubber is controlled largely by noncirculation of air. This condition of dead air acts in turn as an insulation, permitting only very minute or minimum quantities of oxygen to react with the elements of the rubber.

The best type of rubber stowage can be maintained under ground, provided excess moisture is eliminated. This stowage, when under 2 or 3 feet of earth, will maintain nearly a constant minimum temperature throughout the day or season. However, the simple rubber stowage formula is a cool, dark, dry, clean, ozone-free place closed from air currents.

REPAIR TOOLS AND EQUIPMENT

Tools and equipment adapted to the repair of fuel cells

and flotation gear are divided into nine categories, as follows:

Inspection tools.
Drying equipment.
Surface preparation tools.
Cutting tools.
Cement and solvent application tools.
Patch application tools.
Curing equipment.
Testing equipment.
Layout tools.

Some of these implements are special tools adapted only to rubber work, while others are common tools used in all shops.

Inspection Tools

The inspection tools consist of a vapor-proof extension lamp, a universal ball socket type mirror, and a rounded-point, wooden dowel for checking the interior and inaccessible sections of a fuel cell.

Drying Equipment

A portable engine heater, which circulates warm air, may be used as a drying unit. To hasten drying in confined areas, electrical or steam-heating units may be used. An ordinary bag of lead shot, heated to a temperature of 120° F., may also be used for drying out sections of exposed fuel cell sealant.

Surface Preparation Tools

Surfaces that are to be cemented must be prepared by buffing and feathering. To prepare these surfaces, air motors, buffing attachments, and emery cloth are used.

Pneumatic motors (air drills) for power buffing are of several types. That most commonly used is available in two sizes—model A, with a capacity of 6 cubic feet of air per minute, and the smaller unit, model B, with about 5

cubic feet of air per minute. The buffing attachments used with the pneumatic motor include emery mandrels, emery cartridge rolls, carborundum stones, and rotary files.

Cutting Tools

Several cutting tools are the hot knife, dome nut remover, shears, shoe (skiving knife), mill knife, and the one-ply knife.

A hot knife is a tool for cutting sealant or removing fitting flanges. This tool can be machined from a piece of copper or aluminum for use in an ordinary electric soldering iron. The blade is tapered down so that the tool resembles a rod cutter.

The shoe or skiving knife has a thin, straight tapered, flexible blade, and is used for skiving or cutting excess rubber from repairs. It is also used for beveling sections of fuel cell walls in preparation for repairs.

A mill knife may be used for cutting out damaged and defective sections of fuel cell walls. The prominent feature of this knife is an adjustable blade which can be set for cutting to any desired depth.

The one-ply knife is designed to cut through one ply of the fuel cell wall. It is used mostly where blisters occur on the inner liner.

A rubberized fabric separator is another tool adaptable to separating seams, patches, fitting flanges, etc. It is machined from aluminum or steel, and is designed to contain solvent in the handle. The stem is detachable, and has a small blade which resembles that of the hot knife. A small hole, which allows a small amount of solvent to lubricate the blade and to dissolve cement, is drilled through the stem. When using this tool, it is held at an angle, thus allowing solvent to flow into the blade at the point of separation.

A pair of 10-inch shears is recommended for cutting and beveling repair materials. Many patches for life raft repair are pinked, and for this operation special shears—called PINKING SHEARS—are used.

A dome nut remover may be made from a 5-inch C-clamp, and used for removing damaged dome nuts from metal insert fittings. The center of the screw on the clamp is drilled out and a plunger is machined to fit the hole. One end of this plunger is made into a drift punch that will fit snugly into the dome nut, while the other is the batter end. A shoulder and collar prevent the plunger from falling out of the tool. This plunger is used as a positioner for the cutter and also as a drift punch for removing the damaged nut. The stationary end of the clamp is designed so that cutters of various sizes can be interchanged.

Cement and Solvent Application Tools

Common paint brushes are used to apply cements and solvents. However, solvents are easily applied with a lintless piece of cotton cloth.

Patch Application Tools

Repair patches are applied or stitched to a cemented surface with a tool called a stitcher. This consists of a steel disk or roller of a specified width mounted on ball bearings and attached to a handle. Two widths—the $\frac{1}{4}$- and the $\frac{1}{16}$-inch—are most commonly used.

Curing Equipment

The repair of pneumatic life vests requires a vulcanized patch over the injured area. This type of repair consists of the joining of two or more pieces of rubber by the application of cement and heat. The electric vulcanizer subjects the patch to a temperature of 285° F., which is required to make a homogenous bond between the uncured rubber and the life vest tube.

Testing Equipment

Before a repaired fuel cell is replaced, it must be tested to assure against leakage. This operation requires the use of a mercury manometer for control of air pressure while testing. For shop testing, metal fittings, clamps, and plugs for fuel cell fittings openings are also used to make the fuel cell air tight. Soapy water is used to apply a hydrostatic test if necessary.

Cages on jigs are used when available to air test fuel cells. With this equipment, it is possible to run the air pressure from 3 to 6 pounds per square inch, which provides a more suitable and reliable fuel cell testing method.

REPAIR OF SELF-SEALING FUEL CELLS

The history of self-sealing fuel cells began during World War I. The first recorded attempt to develop a fuel container which would automatically seal itself upon penetration by a projectile was then undertaken by an American aviator. This attempt consisted of wrapping sheets of crude rubber about the airplane wing, securing the sheets in place with common wire mesh.

Self-sealing fuel cells are a vital part of the fuel system of modern military planes. In older planes, when shrapnel or shell struck a gasoline tank, the contents spilled out, not only causing the loss of valuable fuel, but creating a fire hazard as well.

Gas tanks have been made more and more vulnerable by the use of increasingly heavier armament, and the self-sealing fuel cell is a partial answer to the damaging of fuel tanks by gunfire.

Self-sealing fuel tanks, or cells, as shown in figure 173, are made with a center layer of sealant material which softens and expands upon contact with gasoline, sealing the opening. The standard cell, as required by A-N specifications, is a 6-ply material, consisting essentially of three parts—a gasoline resistant inner liner, a middle layer of sealant, and a more rigid, tough outside layer.

P. T. boats and most military aircraft use 6-ply cells, while dive bombers use 12-ply. The self-sealing cells are used not only because they retain fuel when punctured by bullets or shrapnel, but because they reduce the danger of fire or explosion when a plane is crash-landed. They vary in shape and size; their capacities may range from a few gallons up to several hundred gallons, depending upon their location and the type of plane in which they are used.

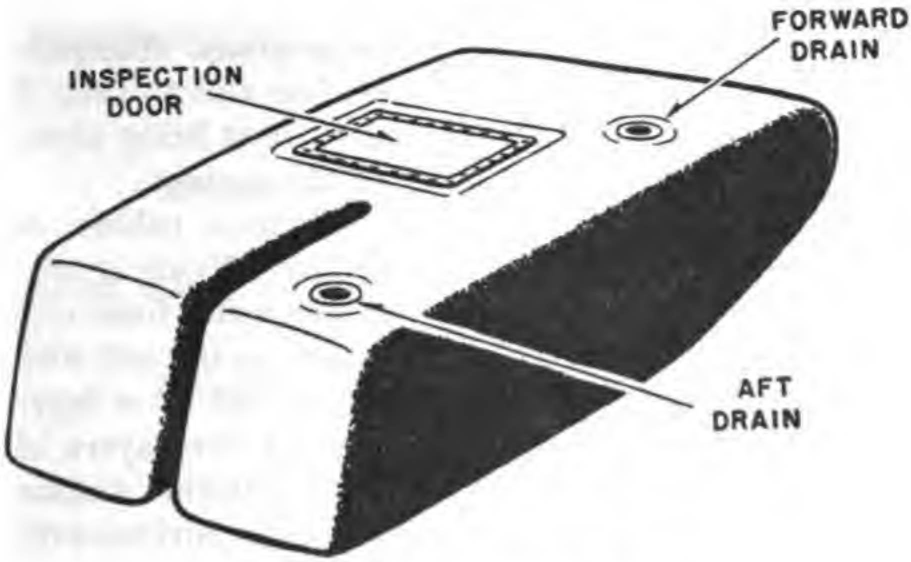


Figure 172.—Self-sealing cell.

Construction

There are three primary layers of material in a self-sealing fuel cell: The inner liner, the sealant, and the retainer. All self-sealing fuel cells now in service contain the basic component parts or additional piles, but each ply may be classified as being related to one of the primary groups.

Nonsealing or bladder-type fuel cells are fabricated in the same manner as self-sealing cells in that they have a liner, nylon barrier and a retainer ply. The sealant layers with their sandwiched-in fabric ply are omitted. All three piles are placed on the building form as one material in the order: Retainer, barrier, and liner.

The component parts are made of the materials listed below:

Liner	Buna-N.
The barrier	Nylon.
The retainer	Special fabric impregnated with Buna-N coating.
Outside finish	Colored Buna-N vinylite.

The major fittings are similar to those used in self-sealing fuel cells except that they have only one flange on the outside (liner side). The cell is made slightly larger than the cavity of the plane, and thus the weight or internal pressure of the

gasoline is borne by the structure of the airplane. The purpose of the interliner is to contain the fuel and to keep it away from the sealing layers so that it will not bring about premature swelling or deterioration of the sealant.

In this construction the Buna-N synthetic rubber or Buna-N coating fabric acts as the interliner. Nylon is used as a barrier to prevent the diffusion of aeromatic fuels into the sealant material. The sealant is placed in the cell with one or two layers which are sometimes divided by a layer of cord fabric retainer material. The final two layers of retainer material are then applied to the exterior sealant layer. The cell is then finished off on the outer surface with a protective coating of buna vinylite lacquer.

The sealant material remains dormant in the fuel cell until the cell is ruptured or penetrated by a projectile. When this occurs it is the function of the sealant to seal the ruptured area so that gasoline will not flow through to the exterior of the fuel cell.

The mechanical reaction results from the fact that rubber, both natural and synthetic, will "give" under the shock of impact thereby limiting damage to a small hole in the fuel cell. The fuel cell material will allow the projectile to enter or leave the cell and then will closely approximate their original position. This mechanical reaction is almost instantaneous.

The chemical reaction takes place as soon as gasoline vapors penetrate through the innerliner material and reach the sealant. The sealant, upon contact with gasoline or gasoline vapors, will extend or swell to several times its normal size. This effectively closes the rupture and prevents the gasoline from escaping.

The purpose of the retainer material is to lend strength to the fuel cell and to protect the sealant and innerliners so that the fuel cell will be capable of withstanding the type of treatment to which the cells often are subjected. This retainer also increases the efficiency of seal action after the cell is penetrated by a projectile.

The standard construction for self-sealing fuel cells as approved by the Bureau of Aeronautics is shown in figure 173.

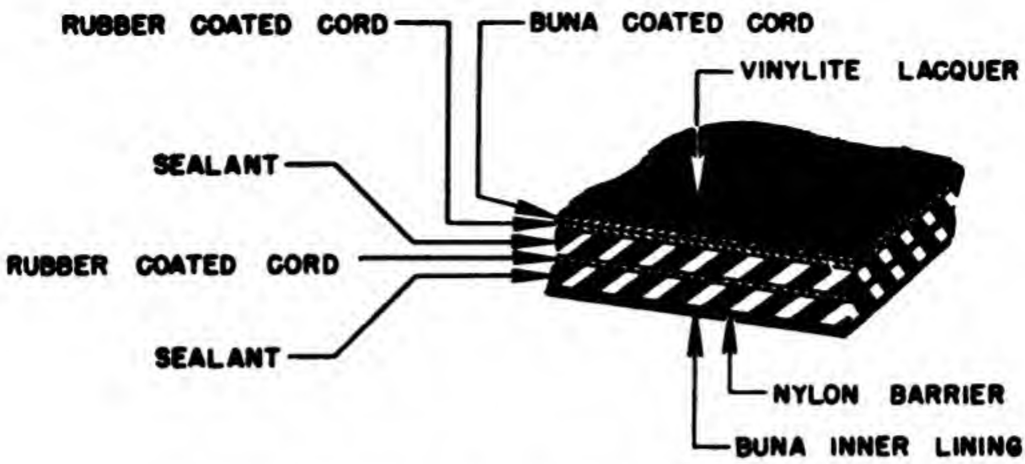


Figure 173.—Self-sealing fuel cell construction.

TYPES OF REPAIRS

If a cell has been damaged, its self-sealing action should not be depended upon for more than a very short time. The cell must be repaired as soon as possible to prevent the gasoline from deteriorating the rubber sealant.

The chief purpose of repair is to restore to the inner liner its resistance to the action of aromatic or high-octane fuel, although it is necessary to restore the strength of the cell wall. The repair of self-sealing cells requires painstaking care to see that each step is properly performed. First of all, it is essential to determine whether the injuries are major or minor. A minor injury is any type of flat surface injury, such as a blister, a loosened seam, or a cut or puncture under 2 inches in length. Major injuries are those which extend over an area of 2 to 10 inches. Injuries greater than that are repaired only in cases of dire emergency. Replacement of fittings or flow tubes is considered a repair to a major injury.

Since the time and effort required for making temporary repairs is as great as that necessary for permanent repairs, all repair methods should be of the permanent type.

REMOVAL OF THE CELL

Fuel cells must be removed from the plane in most cases to make repairs properly and in order to inspect the cell.

The removal of the cell is an important and difficult operation and must be carefully done to avoid injury, which could easily be caused by improper handling. The steps listed should be followed if the cell is to be removed without further damage.

Completely drain the gas from the cell, then make certain that all inspection doors or hand hole covers are removed to facilitate access to all parts of the cell. Disconnect all hoses, tubes, and wire fittings so that the cell may be removed from the cavity.

Collapse the cell by pulling inward on the large surfaces, holding it in the collapsed condition with straps. Remove the cell with as little distortion as possible. Mark the injury, or the reason for removal, so that others will know the course to follow in its repair or salvage.

Place all small parts and screws for each fitting in separate containers, keeping all parts of the cell together to prevent loss.

Jostle the cell to facilitate removal, and sprinkle it with talc or powder if it becomes necessary to squeeze the cell around or between the structural members.

REPAIR OF SELF-SEALING CELLS

Since a large proportion of the time expended in the repair of self-sealing cells is used in the removal and installation of the cells, it is desirable to make a permanent repair if the cell must be removed. By using approved repair materials for the inside and outside, injuries except those to fittings can be permanently repaired.

Permanent repairs may be made to a hole or crack on the flat wall of the cell, or to a corner, seam, or blister. Holes may be filled by the plug or slug of the same material and construction as the cell. Repairs to corners require particular care to insure a leakproof cell.

The inside rubber material consists of two layers of synthetic rubber, cemented together, one of which is vulcanized, the other unvulcanized, and in contact with Holland cloth.

Type of repair	Buffing area		Patch sizes			
			Inside		Outside	
	Inside	Outside	First patch	Second patch	First patch	Second patch
Minor (under 2 inches)	2½ inches beyond injury.	3 inches beyond injury.	2 inches beyond injury	None	2½ inches beyond injury.	None.
Major (2 inches and over)	do	4 inches beyond injury.	do	do	do	3½ inches beyond injury.
Hole type	do	do	1 inch around injury.	2 inches around injury.	2½ inches around injury.	3½ inches around injury.
Corner	do	3 inches beyond injury.	1 inch beyond injury.	2 inches beyond injury.	2½ inches beyond injury.	None.
Blister	do	None	2 inches beyond injury.	None	None	Do.
Seam	do	do	do	do	do	Do.

Chart 21.—Buffed areas and patch sizes for fuel cell repair.

Before removing the Holland cloth, buff the exposed side of the repair materials. The unvulcanized face, which is in contact with the Holland cloth, can be identified by the slightly tacky feel.

The cement is prepared by thoroughly mixing 5 teaspoons (12.5 cc.) of accelerator with 1 pint of cement.

Inside repairs should be made before those on the outside. To accomplish this step, measure the size of the hole or injury and mark the outline for patch size which should extend 2 inches beyond the edge of the injury. Buff the inside of the cell around the edges of the injury for a distance of 2½ inches in all directions, with clean emery cloth. All inside repair buffs should be covered with fine scratches. After buffing, wash the surface with a clean rag dipped in solvent.

Cut a piece of inside repair gum with smoothly rounded outline and skive the edges by tilting the shears when cutting the material.

Support the liner around the injury so that the edges of the injury will be in proper alignment. Apply a thin coat of cement to the buffed area around the injury and the unvulcanized side of the patch. Allow to dry, and apply a second coat to the cell and patch.

AIRCRAFT FUEL SYSTEMS

A fuel system can be defined as a series of units which care for the storing, cleaning, and delivering of fuel to a carburetor under the proper pressure and in sufficient quantities to meet the demands of an engine.

A fuel system, as shown in figure 174, consists of two major sections—the storage and the pumping section. The storage section is composed of fuel cells (one or more to a tank), vent systems, outlet strainers, filler necks, dump valves, solenoid valves, fuel lines, quantity gages, and selector valves. The pumping section consists of an auxiliary fuel pump, fuel lines, master strainer, and engine-driven fuel pump.

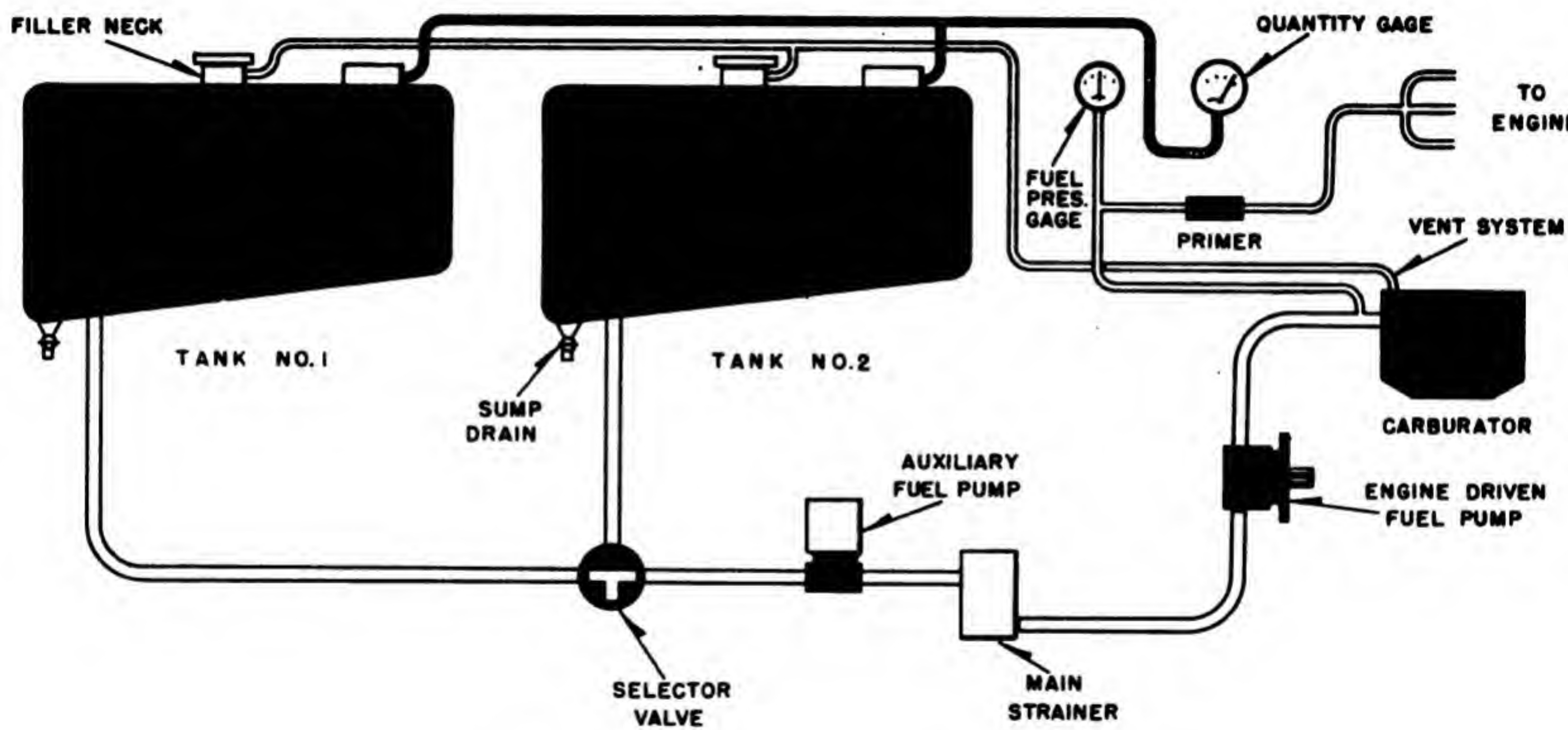


Figure 174.—Typical pressure-type fuel system.

A single-engine aircraft fuel system is examplified by the F6F. The pattern of units shown in the typical fuel system, figure 175, is closely followed.

Variations in storage sections on single-engine aircraft are much more common than in pumping sections. In the F6F, there are two main tanks with self-sealing fuel cells located in the wing center section, and a reserve fuselage fuel cell below the cockpit. These three self-sealing cells are supported by means of a hammock, as shown in figure 176.

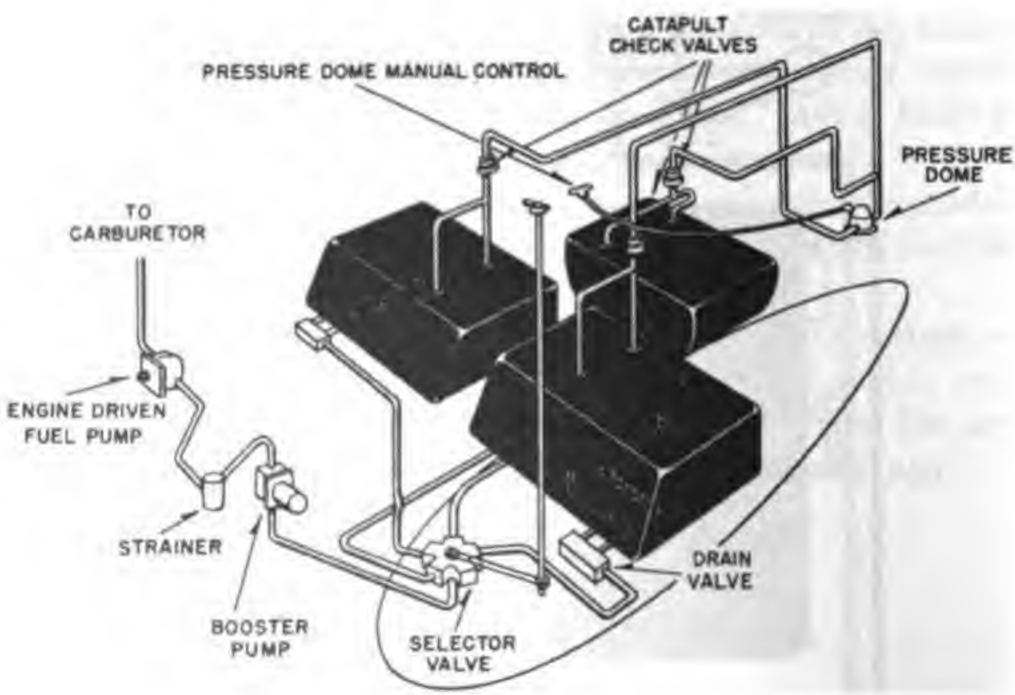


Figure 175.—F6F fuel system.

These hammocks eliminate complete support of the fuel cell by the aircraft structure. In this type of construction, the hammock absorbs the shock of the ram action caused from bullet penetration, relieving much stress from the structural members. The main fuel cell hammocks are suspended by bolts from the wing box beam in the center section. The reserve tank hammock is suspended by bolts from the cockpit deck structures.

Figure 176.—F6F fuel-cell hammock.

The successful flight of an aircraft depends upon the steady flow of fluids which are its life stream. One of these fluids is aromatic fuel.

With the development of long-range aircraft, it became necessary to utilize all available space for fuel storage, and this increase in fuel capacity demanded a greater number of lines, fittings, and connections. These additions increased the chance of damage to the fuel system through enemy action and work hardening of rigid tubing due to vibration.

With these facts in mind, it was necessary that some material other than aluminum alloy be used in the construction of fuel lines. Rubber was the choice, and the results were the various types of aircraft hose now in use.

All hose shall be visually checked at each 30-hour check. Replacement shall be effected whenever deterioration is evident or doubt exists as to the condition of the hose. Deterioration may be observed as ply separation (cover, braid, or tube), excessive cold flow as indicated by deep permanent impressions adjacent to hose clamps, cracks in the cover revealing inner fabric, hardening and lack of flexibility. Weather checking may be inhibited by the application of Buna-Vinylite lacquer applied to the ends and exterior of the hose.

All hose stored in excess of two years shall be tested in accordance with the latest directives prior to use. Hose in excess of 4 years of age shall not be used in naval aircraft.

Aromatic Resistant Self-Sealing Hose (AN–H–27)

Aromatic resistant self-sealing hose has taken the place of aluminum alloy tubing fuel lines on current aircraft. Its purpose is to eliminate the work-hardening factor due to vibrations, and to seal leaks due to the penetration of the fuel lines.

The construction of this fuel hose consists of three plies—the internal, which is composed of a heavy, thick synthetic Buna-N rubber; the middle, which is a closely braided rayon

cord, and the outside, which is a thin layer of synthetic rubber.

Its identification marking is one solid red line or stripe; manufacturer's name, construction number, date of manufacture, in quarter and year.

Fuel, Oil, and Coolant Hose (AN–H–35)

Aromatic resistant synthetic hose is not used where self-sealing qualities are required, AN–H–35 hose is suitable for use in fuel, oil, water, and/or alcohol, and liquid coolant lines in aircraft engine installations. It is constructed to permit assembly with standard hose fitting connection ends, pipe thread adapters, and hose clamps conforming to drawings AND–10058, AND–10060, AN–840, and specification AN–C–140, respectively. The tube of the hose is a seamless, continuous extrusion of a suitable synthetic rubber compound. The outer fabric may consist of one or two braided plies with a protective outer coating. Hose is identified by one broken red stripe; one white stripe consisting of AN–H–35, size and date in quarter and year. This hose supersedes AN–H–26, M–709, and AN–ZZ–H46A. However, existing stocks of AN–H–26 and M–709 hose may be used if tests prove acceptable.

Hydraulic, Pneumatic, Fuel (Including Aromatic) Oil and Coolant: Flame Resistant Hose (AN–H–24)

This hose is a medium high-pressure type hydraulic hose consisting of a seamless compounded inner tube with one wire-braided ply between two cotton braided plies. This hose is used with detachable end fitting AN–782 to form AN–6271 assemblies in hydraulic and pneumatic systems. It is also used with detachable and end fitting AN–792 to form AN–6264 assemblies in fuel, oil, and coolant systems. This hose may be identified by two broken yellow stripes, size, date in quarter and year, the –4, –5, –6 sizes also include "3,000 p. s. i." This hose supersedes AN–H–6 although the latter may be expended if tests prove acceptable.

Hydraulic and Pneumatic Hose (AN–H–28)

This hose assembly is a high-pressure type used in 3,000 p. s. i. as well as 1,500 p. s. i. systems. Construction consists of a thin synthetic rubber inner tube, two wire-braided plies and a synthetic rubber or rubber impregnated braided fabric. It is used only in AN–6275 assemblies with swaged fittings. This hose assembly may be identified by one broken yellow stripe; class B includes "W" size, date in quarter and year. Class A hose also includes "3,000 p. s. i."

Instrument Hose (AN–H–29)

This hose is suitable for use in low pressure flexible hose assemblies for fuel, oil, hydraulic, pneumatic, and coolant systems. Construction consists of a thin synthetic rubber inner tube; one braided-fabric ply and a synthetic rubber cover or additional braided ply in lieu of cover. It is used with AN–775 detachable end fittings to form AN–6270 assemblies, and may be identified by one broken yellow stripe which includes "LP," size, date in quarter and year.

INSTALLATION OF FUEL HOSE

In general, replacement of flexible hose shall be made with hose or hose assemblies of the same size, length, and design as the original parts, unless otherwise indicated by superseding drawings or technical directives. Hose assemblies shall be installed with sufficient length to prevent longitudinal stresses being imposed. Hose shall be installed so that the identification stripe is straight after installation and shall retain at least the bend radius and equivalent support as the installation being replaced.

Lubricants should not be used when installing any type of fuel hose. In fact, to insure that hose does not blow off, fuel hose should be inspected for the presence of mandrel lubricant (graphite) and cleaned with Stoddard's Solvent prior to installation.

AIRCRAFT TIRE MAINTENANCE

With the development and use of faster and heavier airplanes, it is apparent that more careful tire maintenance is necessary. Inasmuch as the care, use, and wear of an airplane tire varies considerably from that of an automobile tire, special consideration of aircraft tire maintenance is essential to our discussion.

Aircraft tire maintenance may be divided into three different phases, each important for obtaining the maximum use of an aircraft tire. These three phases are as follows:

Line inspection.
Tire mounting and dismounting.
Tire and tube inspection after removal.

Figure 177 shows a typical aircraft tire casing construction, and will facilitate a better understanding of the description of this material which we will consider.

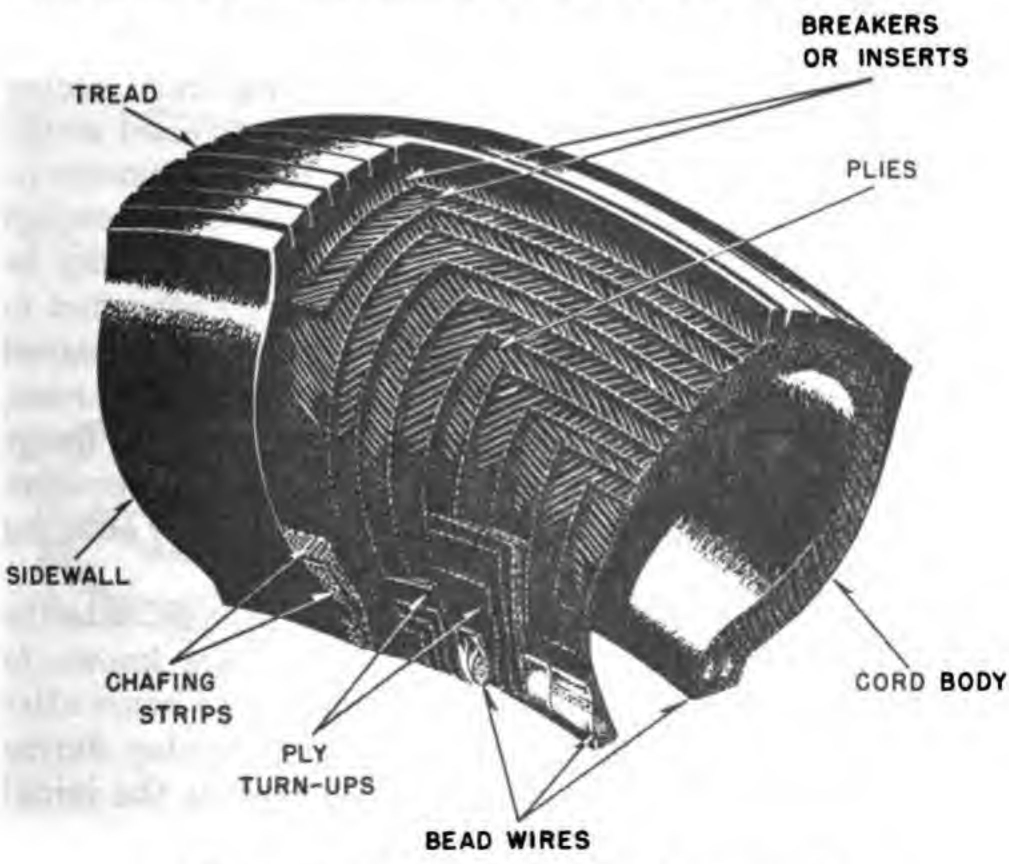


Figure 177.—Typical aircraft tire casing construction.

Correct inflation pressure, as specified in the Erection and Maintenance Manual, must be constantly maintained. In many instances, correct tire pressure will be stenciled on the wheel fairing. Particular attention should be given to tail wheel tires, as they may lose pressure more rapidly due to their smaller volume of air.

In retreading, in order to secure adhesion between the new tread to be applied and the old carcass, it is necessary to have sufficient rubber on the carcass for buffing. When a tread is worn to a point where the outer ply has been damaged, the casing is no longer suitable for reconditioning. Accordingly, care should be taken that tires are not worn through to the cord body. Casings having tread designs should not be worn beyond the point where the design begins to disappear. Smooth tread tires shall be worn to the point where approximately one-fourth of the tread material remains.

When a casing shows evidence of cupping from camber condition, the casing should be removed and reversed on the same wheel. In some instances, camber maladjustments or toe-in will cause wearing in spots of one side of the casing.

Tread cuts which do not penetrate the fabric may be cleaned, filled with commercial tire filler, and cemented in place. If side wall blisters are present that can be cleaned and repaired with no damage resulting to the fabric carcass, or if the rubber fairing immediately above the rim flange separates from the fabric carcass with no injury apparent to the carcass, the damaged area may be repaired by cleaning with wash thinner or gasoline.

All nylon casings have the word NYLON branded into the sidewall during manufacture. These tires are known to stretch throughout a period of approximately 24 hours after initial inflation, and flatspots are likely to develop during this period if the tires are loaded. To prevent the initial formation of flatspots on new nylon casings, the following procedure is recommended.

Mount the casing and inflate to normal air pressure for

as long a period as possible prior to installation on the airplane, or application of load. Where practicable, this period should not be less than 24 hours.

In cases where flatspots are repeatedly encountered with nylon casings, they may be held to a minimum by moving the airplane sufficiently to shift the contact surface by at least one-third of the circumference. In severe cases involving long, idle periods, it is best to remove all static load from the troublesome casing until it is returned to normal operations.

TIRE MOUNTING AND DISMOUNTING WITH POLT TIRE MACHINE, MODEL F.

The Polt tire machine, model F., is designed for wheels up to and including 56 inches. To use this machine, proceed as follows:

1. Roll the wheel on to the stand and place the correct size cone in the hub of the wheel.

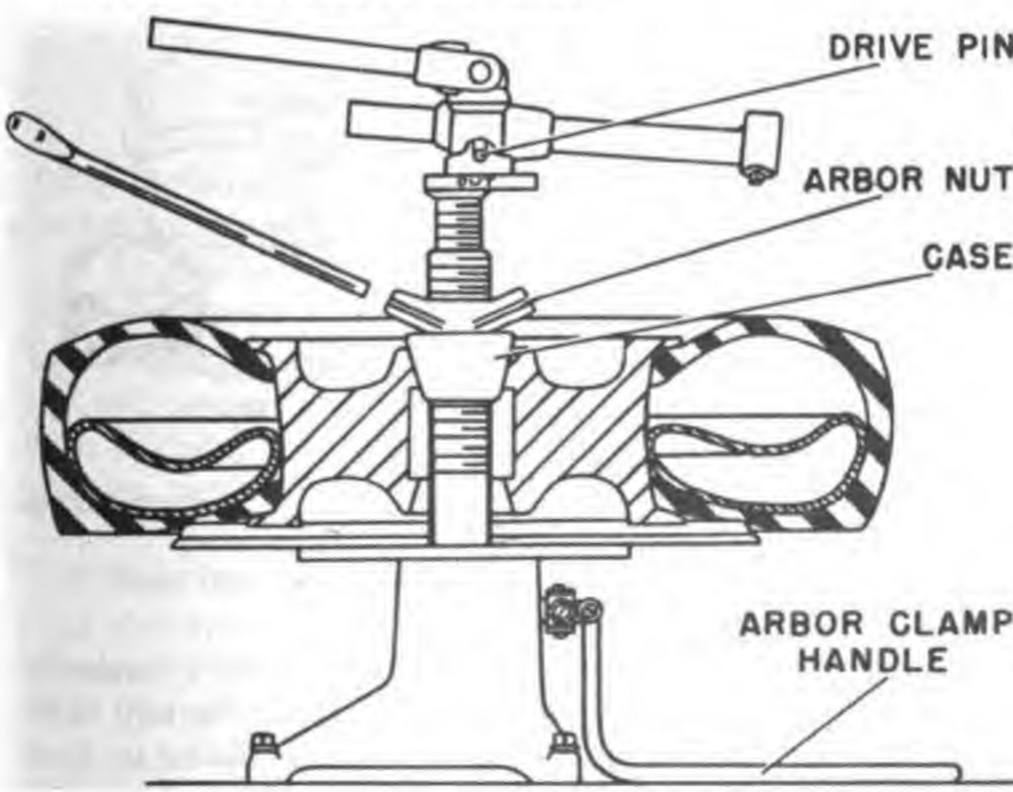


Figure 178.—Tire in position for stripping operation.

2. Put the arbor with the nut and eccentric assembly in place.

3. Lock the arbor clamp by moving the handle at the bottom of the machine to the left then tighten the arbor nut with a tire iron.

Figure 178 shows the tire correctly mounted on the machine ready for the next operation which is stripping the bead from the rim of the wheel. To strip the bead:

1. Engage the drive pin with the hole marked "out".
2. Place "on" and "off" tool in the holder as shown in figure 179 and slide the tool holder in and out to obtain the correct starting position with the tool resting on the tire. When the holder and tool are adjusted so that the tool is in proper position lock them in place.
3. Assemble the drive bars and place it in position.
4. Lubricate the surface of the tire that will be contacted by the tool with soap solution.

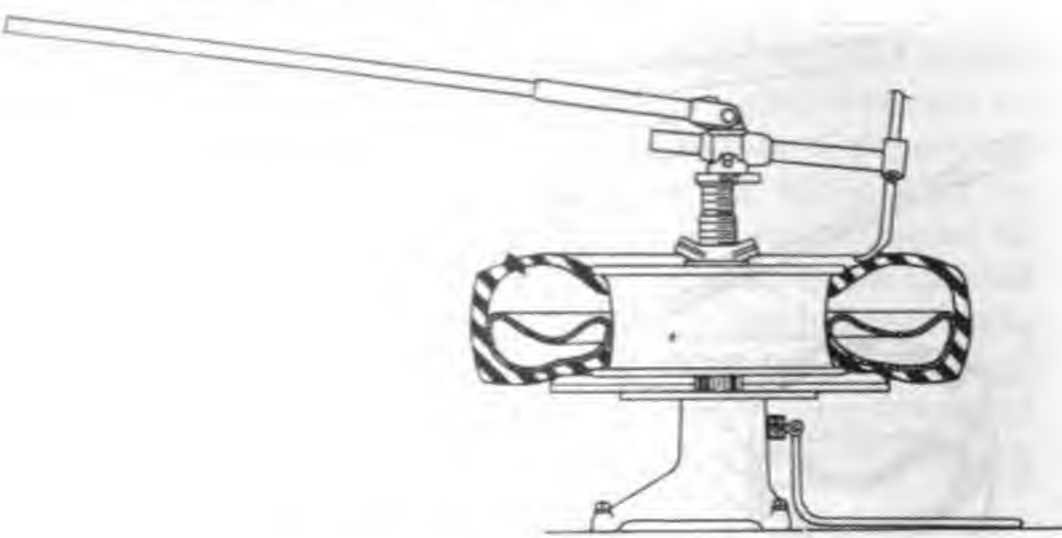


Figure 179.—Stripping tire from bead.

5. To start stripping the bead turn the tool clockwise forcing the bead down far enough to allow the tool to be moved into and under the wheel flange as shown in A of figure 180. When the tool is in this position disengage the drive pin.

6. Now turn the drive bar clockwise moving the tool under the wheel flange as shown in B of figure 180.

7. Turn the tool clockwise until the bead is free. After the bead is stripped from one side turn the wheel over and repeat the operation to strip the bead from the other side.

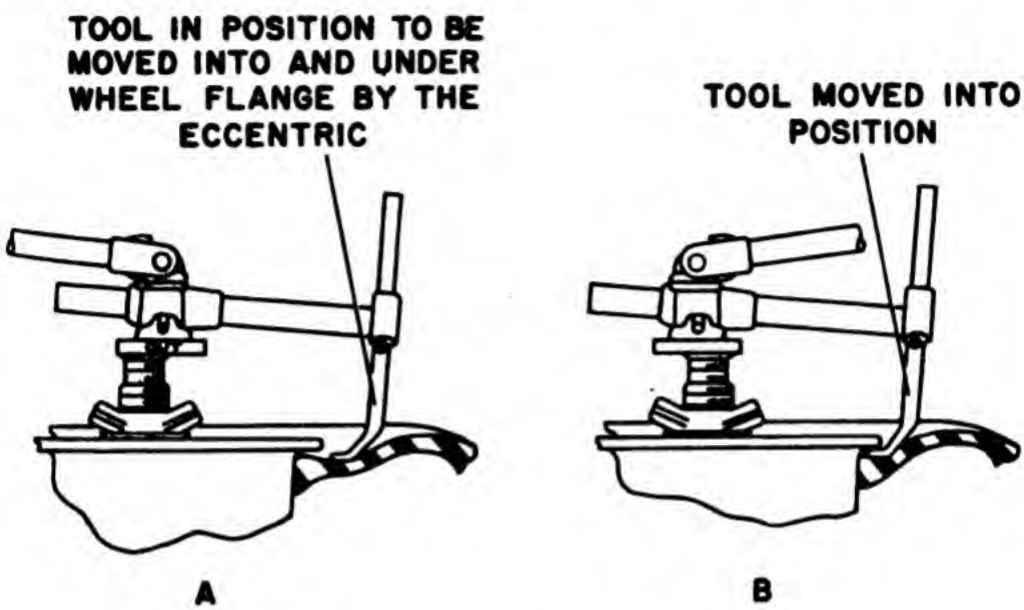


Figure 180.—Stripping detail, A and B.

After the stripping operation is completed the tire is removed from drop center wheels by the following procedure:

1. Engage the drive pin with the hole marked "in" and place the bead supporting block in position as shown in figure 181. Place the tool in the holder and adjust the tool and tool holder so that the tool rests on the wheel even with the edge. (See fig. 181.) When the tool is in this position lock the tool and tool holder.

2. Now depress the upper bead on the side opposite the tool and raise the bead over the tool with the tire iron. Disengage the drive pin. These steps are shown in figure 182. Turn the drive bar counter-clockwise to force the tool under the bead. After the tool is under the bead re-engage the drive pin. As you turn the tool counter-clock-

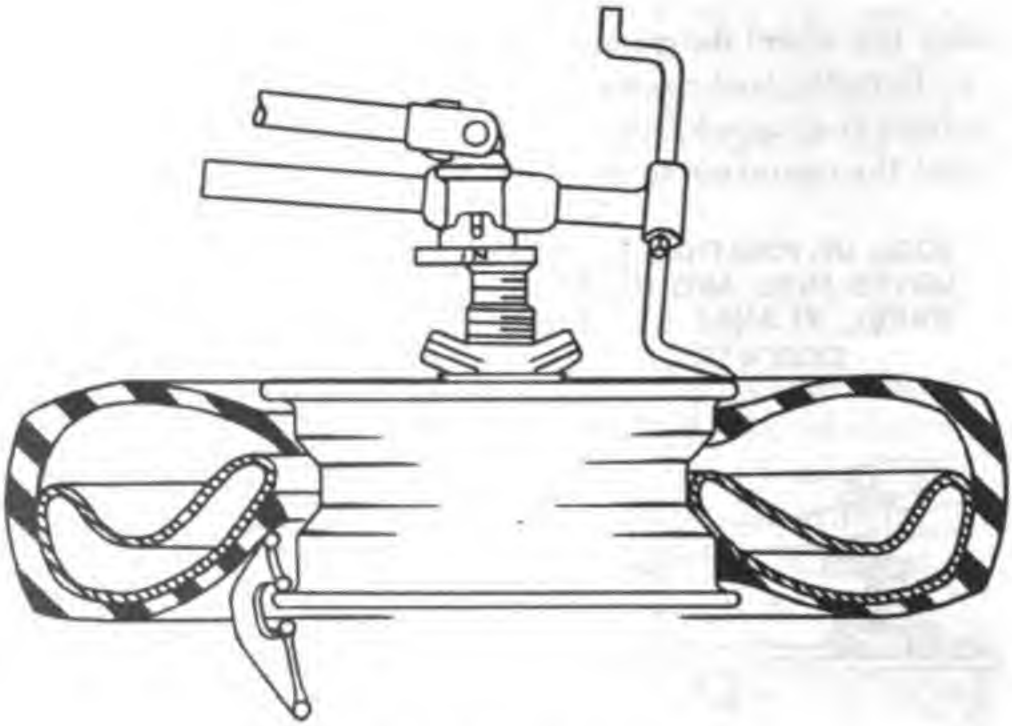


Figure 181.—First step in dismounting tire.

wise to remove the upper bead keep all surfaces in sliding contact, lubricated with soap solution.

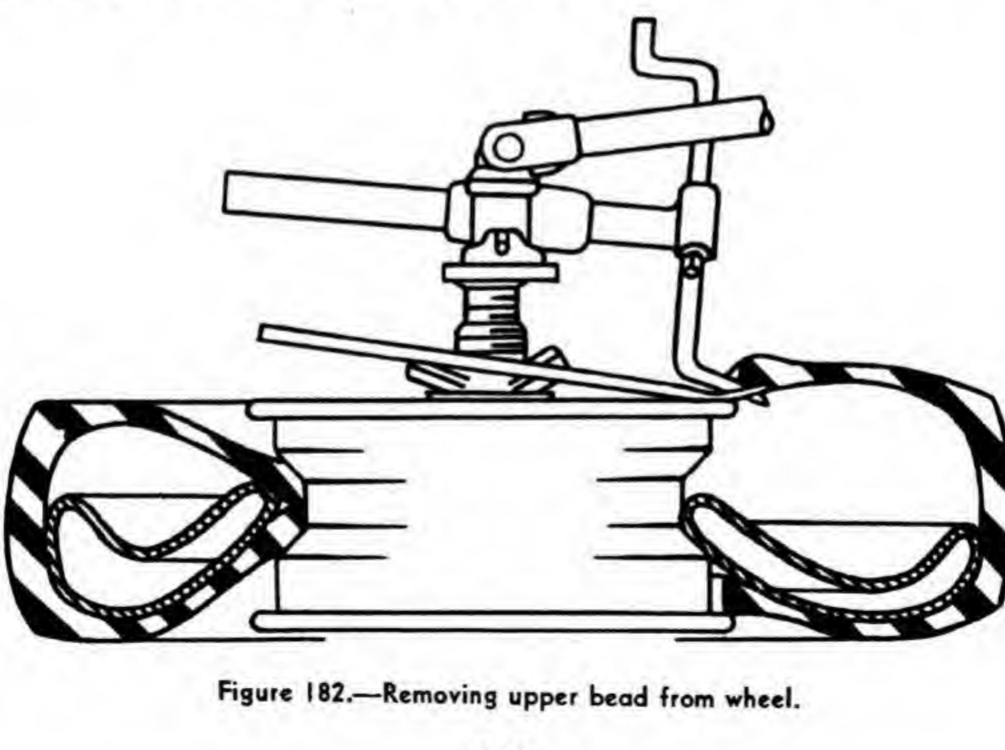


Figure 182.—Removing upper bead from wheel.

3. After the upper bead is removed disengage the drive pin and turn the drive bar clockwise to return the tool to its original position. Now engage the drive pin and remove the tire by following the same procedure as you used to remove the upper bead. Figure 183 shows the final step in removing the tire from the wheel.

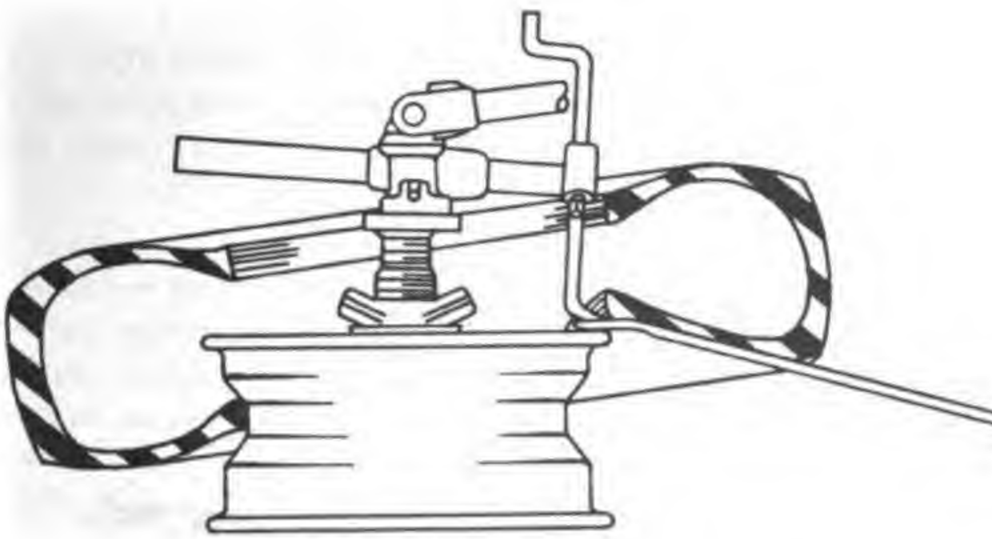


Figure 183.—Final step, removing the tire from the wheel.

To mount tires on drop center wheels:

1. Engage the drive pin in any hole; place the tool in the holder and adjust the tool and tool holder so that the tool rests on the wheel even with the edge. When the tool and holder are in position as shown in figure 184, lock the tool with the tool holder in position.

2. Place the tire on the wheel with one side of the bead in the well as shown in figure 185. Turn the tool counterclockwise to get the remainder of the bead in the well. Keep all surfaces in sliding contact with each other well lubricated with soap solution.

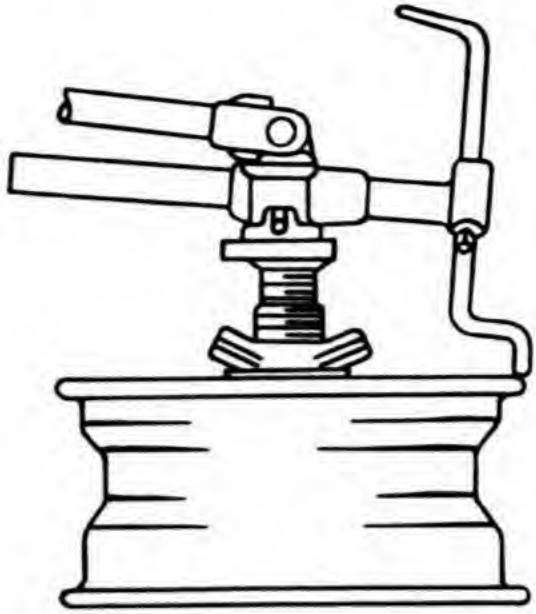


Figure 184.—Tool set up for mounting tire.

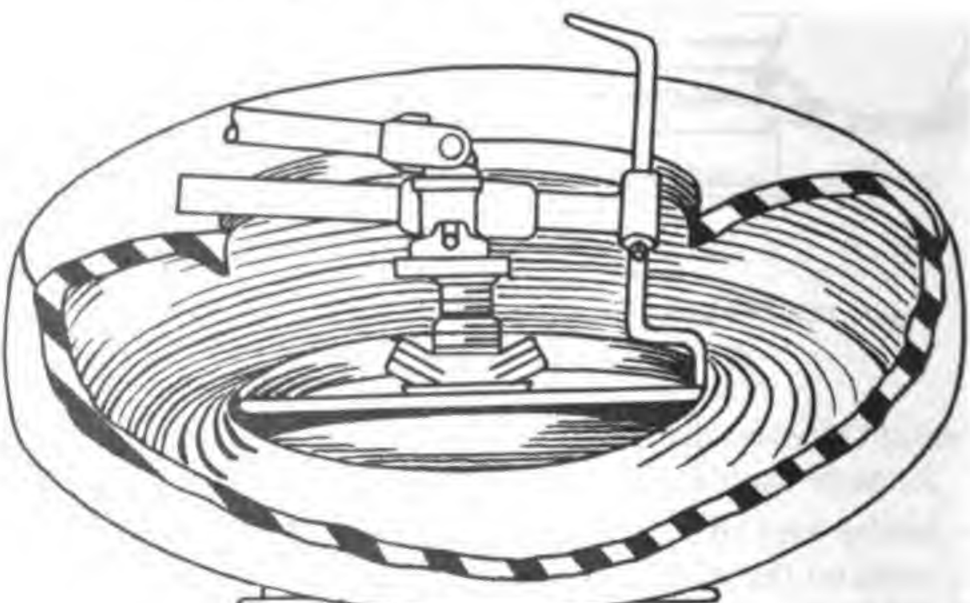


Figure 185.—Position of tire for mounting lower bead.

When the lower bead drops into the well, insert the tube and turn the tool counter-clockwise to complete mounting the tire. Remove the wheel from the machine before inflating. Before inflating, remove the soap solution from the bead that contacts the wheel flanges with a sponge or cloth.

TIRE AND TUBE INSPECTION AFTER REMOVAL

When the tire and tube have been removed, the tube should be taken from the tire carcass and thoroughly inspected.

Inspect the tube carefully under pressure and submerged in water, if possible, to locate possible leaks. Tubes with severe wrinkles must be removed from service.

Check the valve to be sure that the threads are not burred, so that the valve core and valve cap fit properly. If the threads are burred, the valve can easily be retreaded by use of a valve repair tool (Schrader No. 6263 or equivalent). If the valve is badly bent, cracked, or severely worn, replace it at once.

QUIZ

1. What are the essentials of rubber storage?
2. What tools would you use for inspection?
3. What should be repaired first, inside or oustide damage?
4. What purpose do hammocks serve other than supporting the fuel cells?
5. How often should hoses be visually checked?
6. What is the maximum age limit for hose for use in naval aircraft?
7. What type lubricant should be used when installing fuel hose?

CHAPTER 10

REPAIR OF TRANSPARENT PLASTICS

TRANSPARENT PLASTICS

Transparent plastics are those which allow sufficient light to pass through for good vision. The plastics used for cockpit enclosures, must be 87 to 90 percent transparent even after severe Navy tests that simulate the actual effects of sun and weather. Two types of plastics are used in airplanes.

Acrylates (methyl methacrylate)
Acetates (cellulose acetate)

The acetates, because they are relatively inexpensive, are used in some basic training planes, and the acrylates in combat planes. The acetates are limited in their use because they discolor, are easily damaged, and are not readily repaired. Both the acrylates and the acetates are thermoplastic transparent plastics.

There are two groups of plastics classified according to the influence of heat on them—thermosetting and thermoplastic. Thermosetting plastics set or harden after heating, and cannot be remelted appreciably after they once attain this condition. Thermoplastic materials are those which soften when heated and harden when cooled. Thermosetting and thermoplastic types are designed for different uses on the plane.

Plastics are made from organic matter—that is, from materials composed of carbon compounds. The raw materials are obtained from coal tar, cotton, or natural gas, and changed into the chemicals needed for a certain type of plastic. For example, the chemicals required to make acrylates are acetone, hydrogen cyanide, methanol, and sulphuric acid. The substances needed to make acetates are cotton lints, acetic anhydride, acetic acid, and sulphuric acid.

SIZE AND THICKNESS

Transparent plastics are manufactured as castings, rods, sheets, tubes, and molding powders. The cast sheet, which is the most useful form in the airplane, comes in thicknesses from 0.060 to 0.250 inch, and ranges in size from 24 by 36 inches to 20 by 50 inches. These sizes may vary slightly and it may be necessary to refer to Navy Technical Orders governing sizes.

DISTINGUISHING FEATURES

In the maintenance and repair of transparent plastics, it is necessary to know the kind of plastic involved. The method used in making repairs for acrylics may be injurious to acetates, and vice versa. The following four tests may be used to differentiate between the two.

Hardness Test

Scratch the surface of the plastic with a sharp instrument. Acrylates are harder than acetates.

Acetone Test

Wet the finger with a solution of acetone, rub it on some spot of the plastics that will not interfere with vision, and then blow on it. Acrylates will turn white, while acetates will be somewhat softened, but will not change color.

Burning Test

Both types will burn like wood, but each has a distinctive odor. The acrylate odor is more pleasant, and this plastic has a steady, clear flame, while the acetate has a more repulsive odor and a sputtering flame with dark smoke.

Zinc Chloride Test

Place a drop of concentrated solution of zinc chloride on the surface of each plastic. Acetates will turn milky, while acrylates will not be affected.

The two most common types of acrylates are Lucite and Plexiglas. Both are trade names for methyl methacrylate plastic.

STORAGE AND CARE OF PLASTICS

Plastic sheets and parts usually are protected by a covering of 50-pound kraft masking paper to which a pressure-sensitive adhesive has been added. Transparent plastic sheets should be stored flat or on edge, and be covered with masking paper. If the material is stored flat, the largest pieces should be on the bottom to prevent overhang which would cause warpage.

The room in which plastics are stored should not exceed 120° F. in temperature, and there should be ample ventilation with no fumes from paint solvents present. Formed sections should be stored so that there is no unusual pressure on any part. Direct sunlight will cause warpage, and tends to cause the masking paper to harden and stick to the material.

CLEANING, POLISHING, AND BUFFING

Whenever transparent plastics are used in aircraft that are in service, they will need frequent cleaning due to the clinging of foreign substances to the surfaces. The plastic parts must be cleaned as often as necessary in order to maintain the highest possible degree of transparency.

If, after removing dirt and grease, no great amount of scratches are visible, the acrylate plastic should be waxed with a good grade of commercial wax such as Permaseal, Simoniz Wax, 3M auto wax, or Duco #7.

Plastics may be polished by hand with a small pad of flannel or other soft cloth. During this operation a suitable cleaner is applied. Some recommended cleaners are: Franklin's triple-life cleaner and glaze, Noxon cleaner polish, Autogroom, Ken-glo, Lincoln M3828 cleaner, Wilco scratch remover, Simoniz liquid cleaner, Duco #7 liquid cleaner, or McAleer's airplane polish.

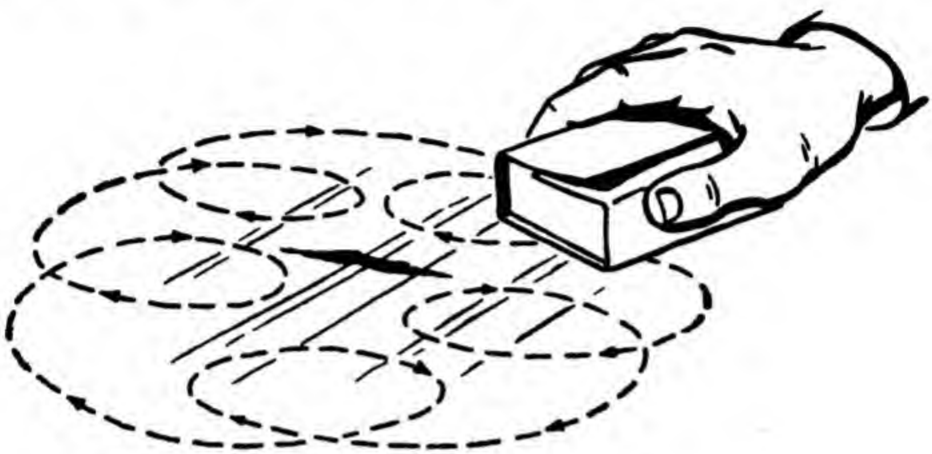
Often after cleaning and polishing, scratches remain, and it will be necessary to remove them by buffing-machine procedure. Soft, open cotton or flannel buffing wheels should be used on acrylic plastics. If no commercial wheels are available, make one by assembling a number of discs of cotton muslin or flannel on a spindle between large washers or face plates.

Standard buffing, or coloring compounds of very fine alumina or similar abrasive are used with a wax, tallow, or grease binder. The finest grades are as coarse as will be necessary for acrylic plastics.

SANDING

Transparent plastics should never be sanded unless absolutely necessary, and then only when surface scratches, which may impair vision, are too deep for removal by buffing. The finest sandpaper that will remove the imperfections should be used. The wet or dry types in grades of 320A to 600 are recommended.

To sand plastics, start with grade 320A soaked in water, using plenty of water while sanding to reduce the heat of friction. Wrap the paper around a block and sand an area slightly larger than the damaged space, using a circular motion with a light pressure, as shown in figure 186. Work with progressively finer grades of paper to grade 600.



SAND WITH CIRCULAR MOTION WITH LIGHT PRESSURE

Figure 186.—Sanding plastics.

The fine scratches produced by sanding should be removed by buffing, if the equipment is available; otherwise it must be hand polished and given a coat of wax as a final step.

CUTTING PLASTICS

As a guide to sawing plastics, the surface is often scribed lightly with a sharp scriber. Thin sheets, up to 0.080 inch, can be broken along a straight scribe line, provided it is marked deeply enough.

Ordinarily, plastics may be cut with any of the saws used for wood or metal, as shown in figure 185. The speed at which a saw blade should run depends upon the thickness of the material and the type of equipment being used. A good approximate speed is 3400 r. p. m. (saws should run at 8,000 to 12,000 surface feet per minute). If the stock is fed

slowly and steadily into the saw, the plastic should not overheat. A soap and water solution (Ivory soap or equivalent), light machine oil, waxed paper, or air blast may be used as a coolant.

Acrylic plastics may be readily filed, scraped, or sanded to give a desired finish. Vixen, rough-cut, or medium-cut files will give the best results.

DRILLING AND TAPPING PLASTICS

In the maintenance and repair of transparent plastics, it will be necessary to drill holes, for example, at the ends of cracks to relieve strains, or to provide a means of attaching panels by riveting, bolting, and screwing. Holes are necessary when making a laced repair. Vertical spindle drill presses are most practical for drilling acrylates.

Figure 187.—Sawing plastics.

Standard drills used for metal may be employed for drilling plastics. Wide flutes are preferred, as they permit the chips to free themselves more easily. To prevent cracking, the drill must be ground so that it has a lip angle of 70° or a point angle of 140°. The lip clearance angle should be 4° to 8°.

The flatter point will allow the body of the drill to enter the work before the point breaks through and thus prevent a wedging action.

The speed for drilling plastic is much slower than that used for drilling metal. The rate of speed should be decreased as the depth increases. Too fast a drill speed will cause plastics to crack and chip. When the correct feed is used, smooth spiral chips will result. Speeds for the various size drills are shown in chart 22.

When drilling plastics it is necessary to provide some means of cooling to prevent binding and grabbing of the drill. Three of the most commonly used coolants are mild soap and water solution, light machine oil, and air cool jet.

Drill diameter	R. p. m.
1/16	7, 330
1/8	3, 670
3/16	2, 440
5/16	1, 470
3/8	1, 220
7/16	1, 050
1/2	920
5/8	730
3/4	600

Chart 22.—Drill sizes for plastic drilling.

TAPPING AND THREADING

The tapping and threading of transparent plastics does not differ from that of metals, and may be done either by hand or machine. Sharp V threads should be avoided. The lubricants used for tapping and threading are a mild soap and water solution, or oil. Hand tapping and threading of holes and rods $\frac{3}{16}$ inch or less in diameter requires no lubrication. Plastics should be tapped more slowly than metal.

REPAIR AND PATCHING

Repairs to plastics may be made necessary by scratches, cracks, or bullet holes. Ordinarily, badly damaged panels are replaced. If the damage is not too severe, emergency or permanent patches may be applied. A part that has been repaired with a permanent patch is approximately 85 percent as strong as the original.

Emergency Repairs

Emergency repairs are those which must be performed hurriedly and with a minimum of equipment. This type of patch should be replaced as soon as possible with a permanent patch, or a new panel should be installed. Emergency repairs obstruct vision, are not weatherproof, nor are they durable enough to withstand the stresses imposed upon them. They may be made in any of the following ways, whether the repair is to a crack or to a bullet hole.

Laced Patch

The first step is to drill a $\frac{1}{8}$- to $\frac{3}{16}$-inch relief hole at the end of the crack, as shown in figure 188. This distributes the stress over a greater area, preventing the crack from spreading. The hole must be directly at the end of the crack if it is to serve its purpose. Then, $\frac{1}{8}$-inch holes are drilled $\frac{1}{2}$ inch from the crack on both sides, spaced approximately

$\frac{3}{4}$ inch apart. Copper wire, strong twine, or a shoe lace is used to secure the crack much in the same manner as a shoe is laced, as may be seen in figure 188. The lacing should be under an even tension.

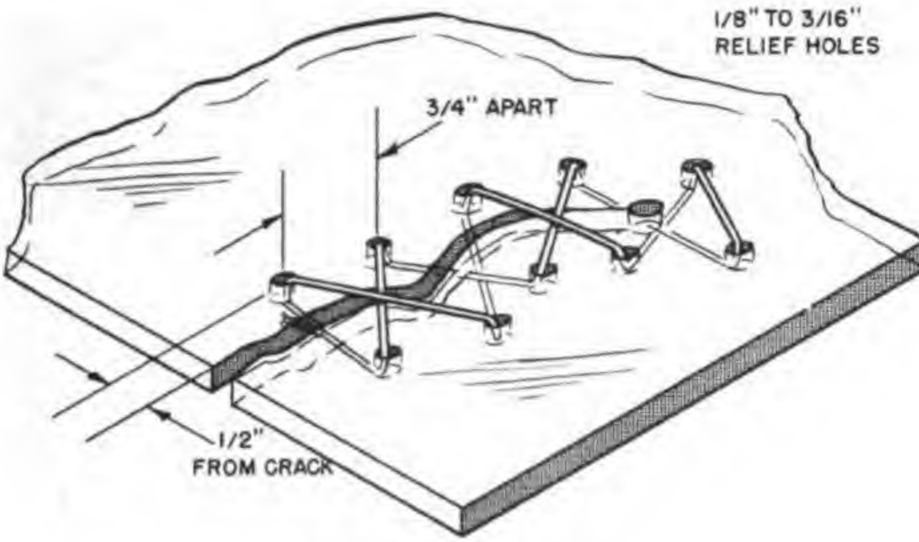


Figure 188.—Laced patch.

Fabric Patch

Grade A airplane fabric, canton flannel, part of a shirt, or similar material can be cemented over the damaged part after the relief holes have been drilled. This repair applies either to cracks or to bullet holes having radiating cracks as shown in figure 189. Each of these cracks should have a $\frac{1}{8}$- to $\frac{3}{16}$-inch relief hole drilled at its end. The fabric should be soaked in plastic solvent or cement before it is applied to both sides of the panel.

Lap Patch

If a piece of plastic as thick as the original is available, it can be cemented over the damaged area. The patch should be well rounded, particularly at the top edges, as figure 190 illustrates. The soak method of cementing is preferred for this patch, although the wood glue method may also be used.

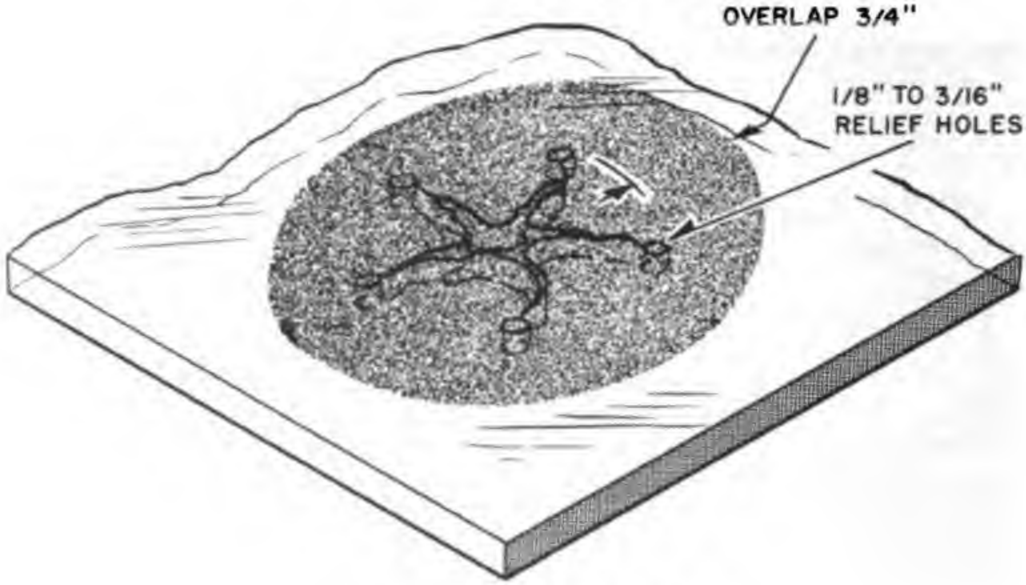


Figure 189.—Fabric patch.

These two methods are explained in our discussion of cementing. Tape should be placed on those parts of the patch and panel which are not to be cemented, and weights may have to be used to apply proper pressure while the cement is drying. When dry, the patch is buffed and polished to improve its transparency.

Permanent Repairs

A permanent repair of a crack or bullet hole can be made by cutting out the damaged area and replacing it with a plug of thicker material. The hole is trimmed to a perfect circle or oval, and its edges are beveled to about 30°. The plug is filled to fit the hole, and its edges given a sharper angle than the hole. After the plug fits the hole closely, it is heated until it is pliable and forced into the hole under a light presure to insure a perfect fit. When it has cooled, it is removed, taped, and cemented into place. After 24 hours have elapsed, the plug is sanded flush with the panel and finished by buffing and polishing.

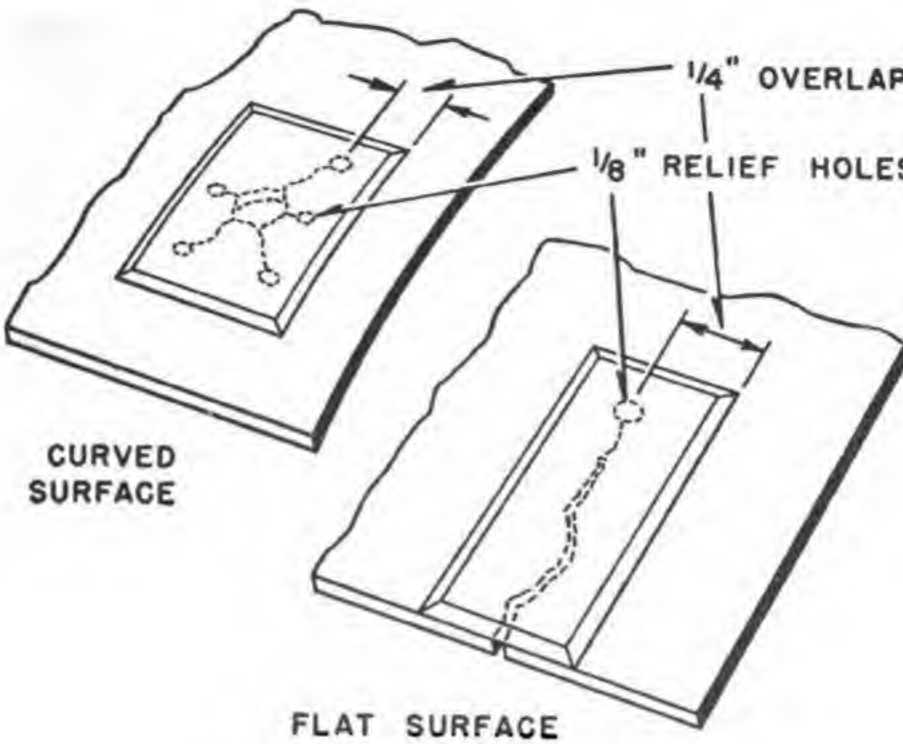


Figure 190.—Lap patch.

JOINING PLASTICS

Plastics may be joined by means of bolts, screws, rivets, or cement. With care and practice, it is possible to obtain a cemented plastic joint closely approximating the original plastic in strength and transparency.

There are a number of different cements used to hold two pieces of acrylic plastic together. The characteristics and uses of the different types are explained in the following paragraphs.

Types of Cement

A monomer (monomeric methyl methacrylate) is a liquid acrylate, kept in liquid state by the addition of a reducing agent known as hydroquinone. This is a commercial cement, is often known as cement X or cement 1A, and is used especially in the soak method of cementing.

In the monomer solvent type of cement, as much as 50 percent methylene dichloride is added to the above mentioned monomer to improve its penetrating power. This type of cement is also used for the soak method.

The value of solvent cement lies in its ability to soften the surface of the acrylic plastic. As the two pieces are brought together, the solvent evaporates and the plastic hardens. The four solvents commonly used are ethylene dichloride, methylene dichloride, glacial acetic acid, and acetone.

Ethylene and methylene dichloride have proven to be the best. Acetone should be used as an emergency solvent only, as it tends to leave the surface of the plastic cloudy or hazy.

To produce the partially polymerized monomer type of cement ordinary monomer cement is heated to its boiling point which is near that of water. After the cement has cooled, it is a little more viscous than glycerine. This cement is used in the same manner as wood glue, and must be kept in a refrigerator to retard hardening. This cement is highly inflammable, and should be heated on an electric hot plate rather than over an open flame.

Solvent polymer cement is one of the most commonly used cements and can be easily prepared. Ethylene dichloride, methylene dichloride, or glacial acetic acid may be used as a solvent. In each case, ordinary acrylic chips or shavings are added to the solvent until a viscous cement is produced. As the solvent evaporates and the cement hardens, more solvent must be added to keep the cement at the proper viscosity. This cement is also used in the same manner as wood glue.

In order to secure the best results, the pieces of plastic that are to be cemented together should fit accurately. All jointed areas should be sanded smooth and cleaned of any foreign substances. Parts that are not in direct contact with the cement should be taped to prevent the cement from marring the plastic. Masking tape should be used on joints to protect the surrounding area. The plastics react to the cement, and would be distorted or lose transparency if unprotected. Figure 191 shows how the tape is applied.

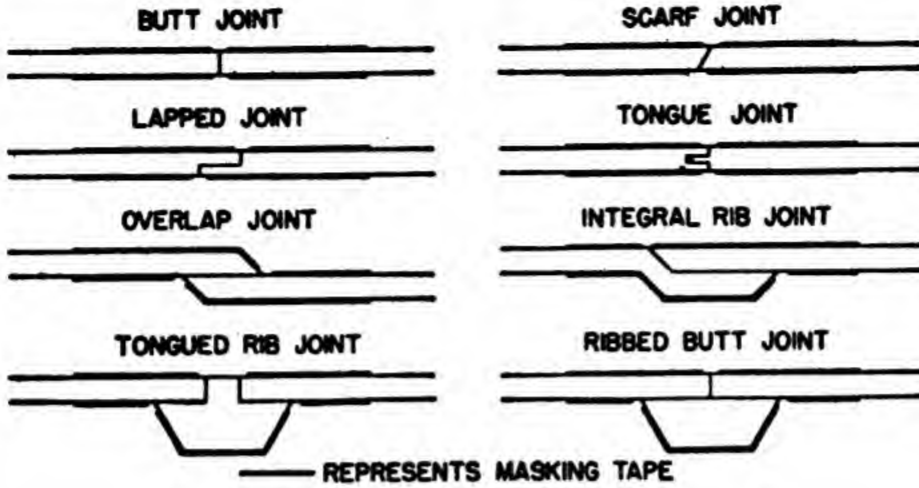


Figure 191.—Taping for different types of joints.

METHODS OF CEMENTING

There are two methods of cementing, commonly referred to as the soak method and the wood glue method. The procedure for each is as follows:

Tape the joint to within $\frac{1}{16}$ inch of the area to be cemented, then place the joint in the cement. Either solvents or monomer may be used. The joint is allowed to soak for a period of time, depending upon the type of cement. If ethylene dichloride is used, soak for 2 to 3 minutes. If monomer is used, soak for 30 to 40 minutes.

After soaking, the joint is placed in position and clamped until dry.

Tape the joint to within $\frac{1}{32}$ inch of the area to be cemented, and apply the prepared glue to the joint in the same manner as the glue would be brushed on a wood joint. Just enough pressure should be applied in clamping to force out all the air bubbles from the surface of the edge. In many cases, the success of a cementing job depends upon the method used for clamping the joint together while drying. Clamps or jigs should be applied evenly over the surface to keep the joint under as much pressure as is practicable. Precautions should be taken to see that the two pieces of plastic are not forced out of shape so that one or the other piece will be crazed.

There is no set rule for clamping plastics into position, but figure 192 will furnish a general idea of how the clamping may be accomplished.

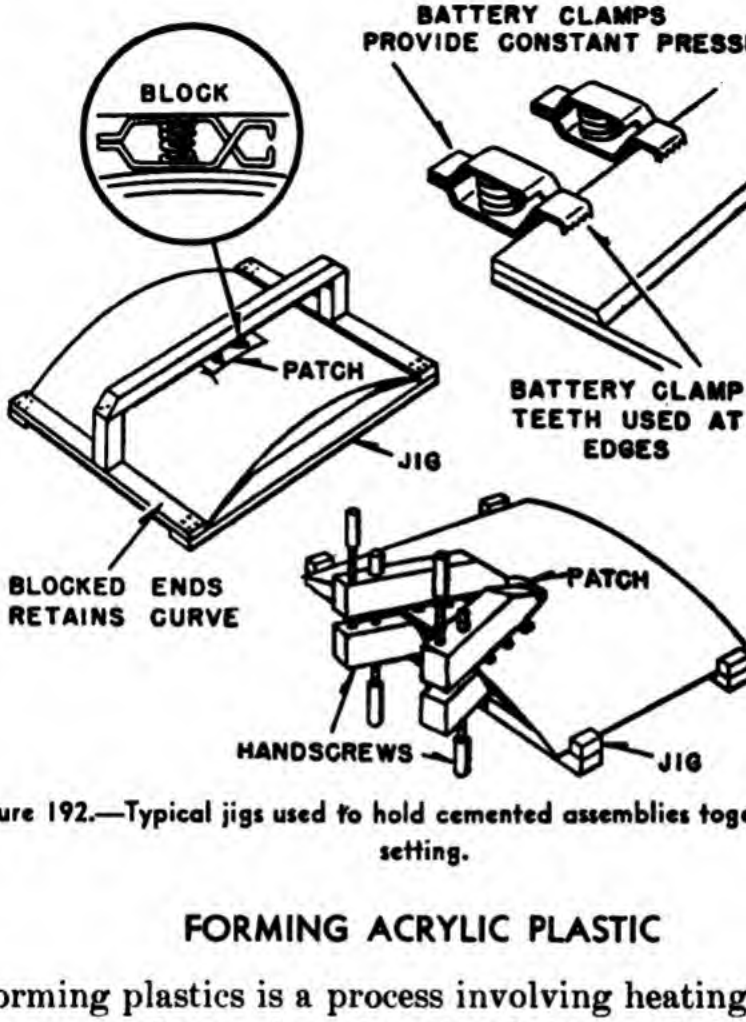


Figure 192.—Typical jigs used to hold cemented assemblies together during setting.

FORMING ACRYLIC PLASTIC

Forming plastics is a process involving heating to a given temperature for a given length of time and then bending over a form or pattern, as shown in figure 193, to obtain the desired shape. Only the thermoplastics—which include acetates and acrylics—can be formed, since they can be made pliable by heating. There are two common types of forming—monocurve, or simple forming, and multicurve, or stretch forming. Monocurve forming is that in which the plastic is curved or bent in one direction only. In multicurve forming, the plastic sheet is stretched so that it is curved in more than one direction. An example of this would be the forming of a ball-shaped part over a round

form. Forming of plastics is necessary for the repair of windows, installation of curved panels, form patches, and fabrication of miscellaneous parts.

Heating Methods

Plastics may be heated for forming with any of the following mediums:

Electricity.

Gas.

Steam.

Direct flame of an alcohol lamp or blow torch.

Any indirect hot-air oven is most satisfactory. A suggested type of oven is shown in figure 194. The oven of an ordinary gas range may be used if a temperature control is provided. The sheets may be hung vertically on clamps, or placed in a horizontal position on cloth or felt.

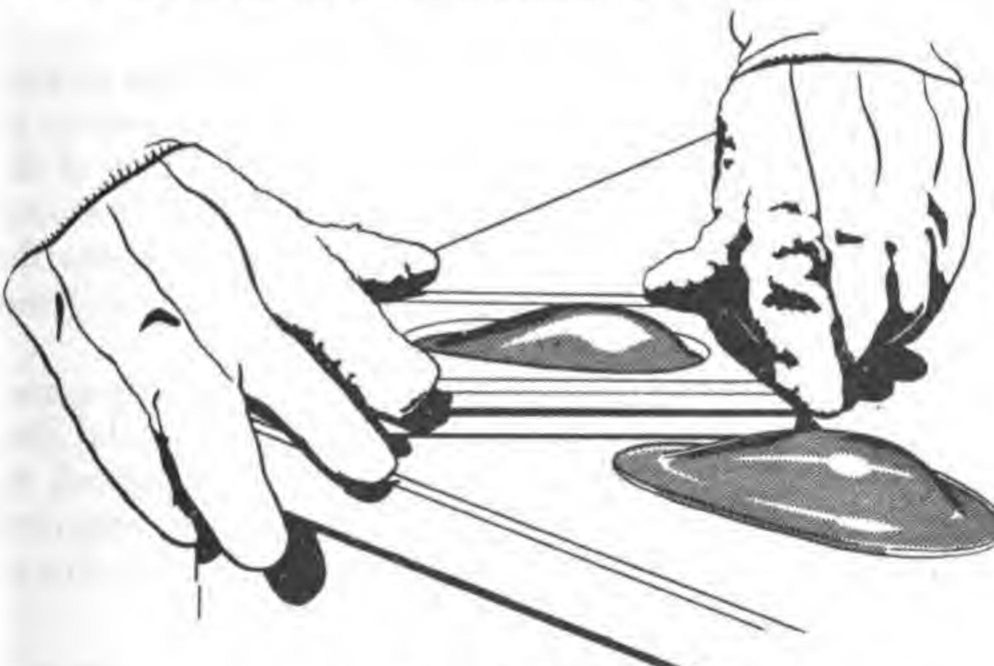


Figure 193.—Forming plastic.

The forming temperature for each plastic is different. For acrylates, the temperature ranges from 200° to 300° F. For monocurve forming, the temperature varies from 248° to 284° F., while for multicurve forming the temperature should be nearer 300° F. The length of time plastic remains

in the furnace depends on the size and thickness of the sheet. Usually, it should be heated from 5 to 20 minutes.

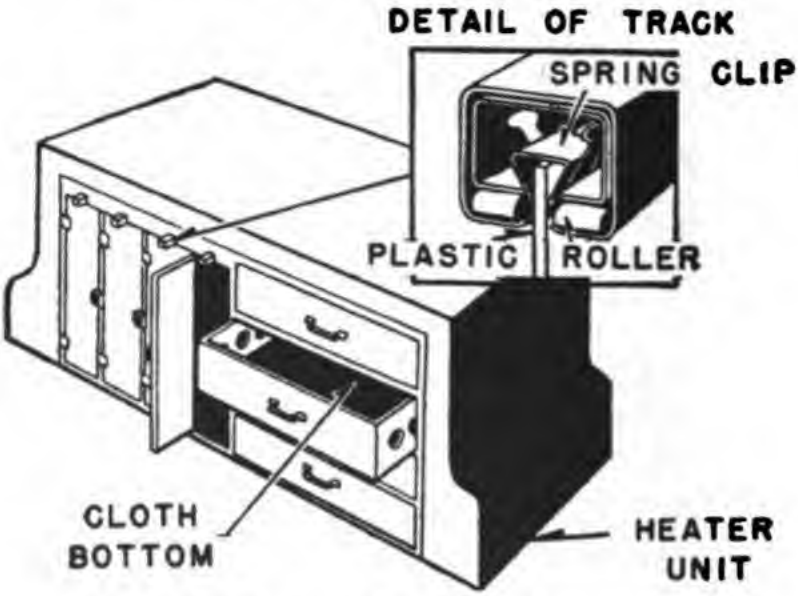


Figure 194.—Suggested plastic oven.

Strains in the plastic can be kept to a minimum by making sure the material is properly heated before attempting to form it. If it is too soft, flaws will develop. Two of the common flaws are markoff and crazing. Markoff is a term applied to imperfections and identations pressed into the soft plastic from a badly made from, or caused by incorrect handling of the hot sheet.

Crazing refers to fine surface or internal cracks caused by stress exerted in a plastic sheet, which weakens the plastic and causes lack of transparency. It is produced by forming a sheet that is not sufficiently hot, by abnormal stresses applied to the sheet, or by using the wrong type of cleaners.

INSTALLATION OF PLASTICS

There are numerous types of devices used for the installation of plastics. The following is a list of the more common types used.

Extruded U- or H-channels.
Flush channels.
Ribbed Channels.
Wedge section installations.
Nut, bolt, and rivet mountings.
Patented channel installations.

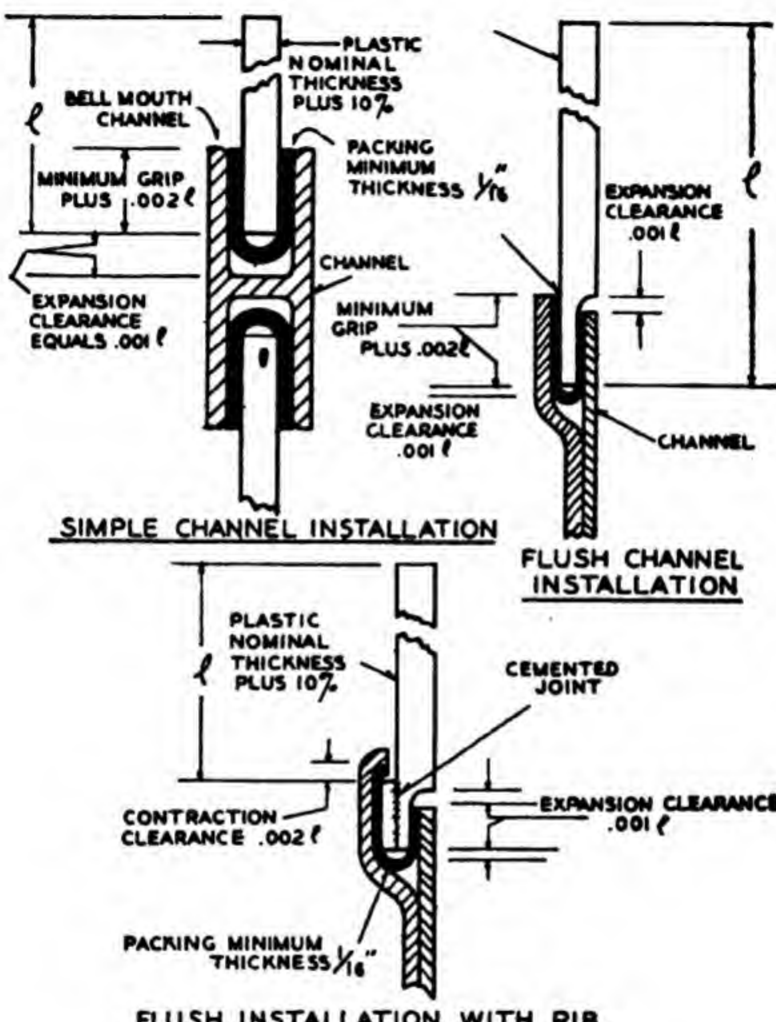


Figure 195 a.—Types of plastic installations.

Some of these installations are shown in figure 195. Whenever possible, bolting and riveting through holes drilled in plastics should be avoided. Channel and clamp mountings are preferable because of their ease and speed of installation. However, where a panel is to be subjected to high stress, it may be advisable to use the riveted and bolted type of mounting.

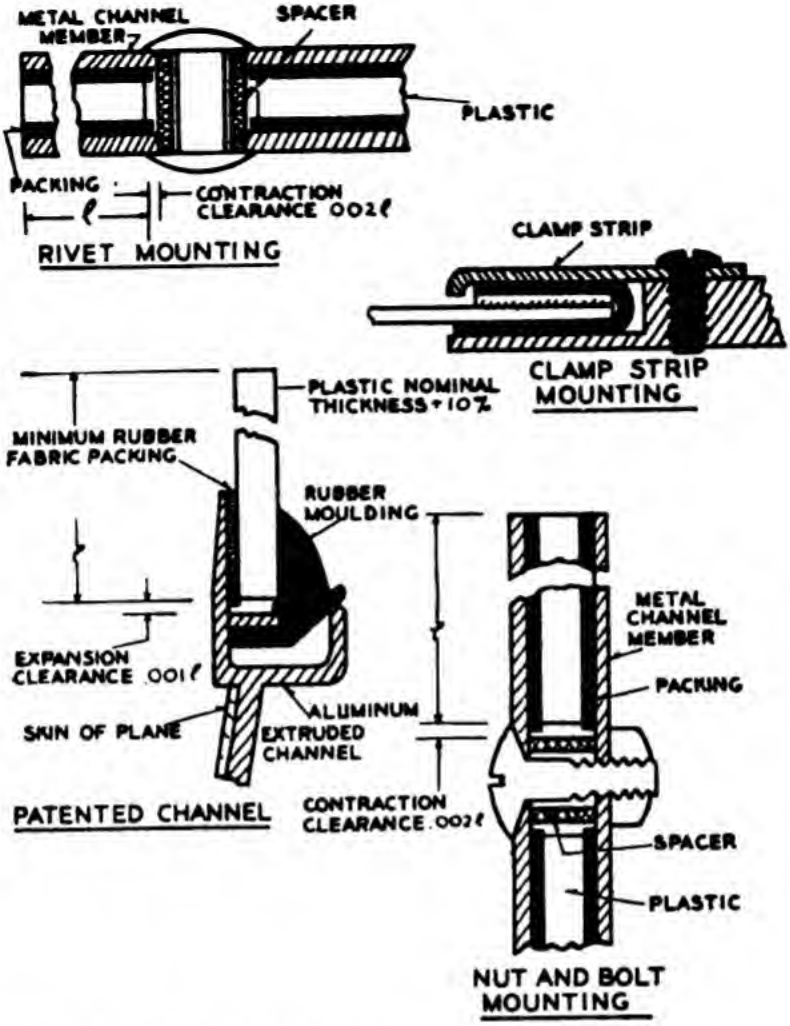


Figure 195 b. —Types of plastic installations.

QUIZ

1. What two types of transparent plastics are used in aircraft?
2. What type of plastic turns white when in contact with a concentrated solution of zinc chromate?
3. How should drills be ground for drilling plastics?
4. What is the first step in applying a lace patch?
5. What solvent cement should be used only if no other is available?
6. How may bullet holes in plastics be repaired?
7. What two types of forming are used with plastics?

CHAPTER 11

REPAIR AND APPLICATION OF FABRIC COVERING

Airplanes of all-metal construction were preceded by airplanes which were fabric covered. Indeed, there was a considerable period of time when all the surfaces of an airplane were covered with fabric, and as a result of widespread use, the technique of fabric application reached a high degree of perfection.

A great deal of research regarding the application of fabric has been made recently. Although the all-metal type of construction is being used throughout naval aviation, there are still certain portions of planes which are fabric covered.

This is particularly true of fighters and some bombers. The use of fabric surfaces on planes of all-metal construction is governed by the designers' requirements for performance. This has resulted in the control surfaces of all-metal airplanes being generally covered with fabric.

Control surfaces are subjected to severe vibration which might cause failures in sheetmetal riveted construction—due to lack of flexibility of sheetmetal skin. Fabric is not subjected to vibration failures. Another advantage lies in

the fact that the covering may be easily removed and the control surface recovered when internal structural inspection or repair is necessary.

Aircraft fabric is ordinarily made of a 60-strand 2-ply yarn, both in lengthwise threads known as the warp and in the cross threads termed the woof or filling. The thread count should be 80 to 84 per inch, which produces a minimum tensile strength of 80 pounds per inch in both directions.

The threads or yarns used in such fabrics are especially processed to remove the fuzz and nap, which results in a smooth cloth. No starch or sizing is used in the weaving, as the absorbent qualities of this fabric are of great importance.

Standard widths of fabric used are 36, 42, 60, and 69 inches. The 36-inch width is most generally used.

THREADS AND CORDS

There are three main classifications of threads used in fabric covering. These include rib-stitching or rib-stringing cord, machine-sewing thread, and hand-sewing thread.

Rib-stitching cord is a heavy cotton or linen cord, ranging in tensile strength from 35 to 300 pounds. It is used for stringing fabric covers to the ribs and for lacing covers around fuselage openings. For rib stringing, the lighter grade of cord is used. The Navy linen cord is a left twist, 9-strand unbleached cord made of unwaxed Irish flax, strong enough to withstand the suction of the air passing over the upper surface of the wing.

Machine-sewing thread used for machine sewing grade A fabric is a left twist, 4-ply unbleached cotton thread, of a size from 16 to 24, having a tensile strength of from 4 to 5 pounds. The left twist is necessary, as many sewing machines have a tendency to untwist a right-hand twist.

Hand-sewing thread of the correct grade should be used whenever it is necessary to sew fabric covering by hand. Either cotton or linen thread may be used for this purpose.

If cotton is used, it must be an unbleached left twist, three-strand, No. 10 thread. Linen thread should be an unbleached left twist No. 30, three-strand thread. Each of these threads has a tensile strength of approximately 9 pounds.

SURFACE TAPE

Surface tape is the finishing tape that is doped over each rib or seam to cover the stitching. It provides a neat, smooth, finished appearance, and can be obtained with serrated or pinked edges, or with a straight edge impregnated with a sealing compound to provide better adherence to the fabric covering. Surface tape is made from grade A fabric in various widths from $1\frac{1}{4}$ to $3\frac{3}{4}$ inches, from glider fabric in $1\frac{1}{2}$- and 2-inch widths, and from a balloon cloth in $2\frac{1}{4}$-, 3-, and 4-inch widths.

REINFORCING TAPE

Reinforcing tape is used over fabric and under the rib stitching to prevent the stitching cord from cutting through the fabric. It is also used for cross-bracing ribs and for binding. This tape has an extremely strong warp. The warp ends are made from cotton yarn No. 20/3/4 or its equivalent, and the filling picks are cotton yarn No. 24/2.

APPLICATION OF CLOTH SURFACES

The proper application of cloth to the surfaces is essential if a good appearance, the best results, and strength are to be obtained from the material selected. A good covering job is not only important from a strength and appearance standpoint, but it affects the performance of the airplane. It is essential that all covering be taut and smooth for best performance. To obtain smoothness, it is common practice to sand the surface after each coat of dope is applied.

All machine sewing should have two rows of stitches with 8 to 10 stitches per inch, a lock stitch being preferred. All seams should be made with the aim of securing the smoothest job possible combined with adequate strength. The lock stitch is shown in figure 196.

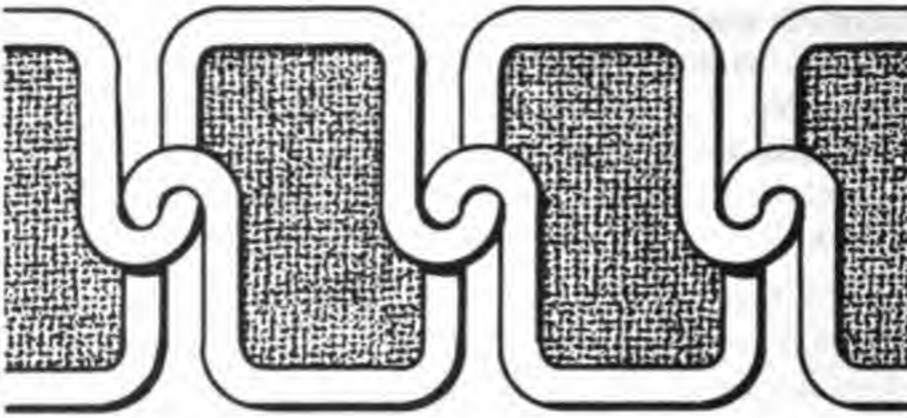


Figure 196.—Lock stitch.

Stitches should be approximately $\frac{1}{16}$ inch from the edge of the seam, and $\frac{1}{4}$ to $\frac{3}{8}$ inch from the adjacent row of stitches. Longitudinal seams should be as nearly parallel to the line of flight as possible.

There are four types of seams, as illustrated in figure 196, which are used to join the edges of fabric widths. The plain lap seam may be used only where selvage edges are joined. A fell type seam is that most commonly used, and is employed where the edges of the fabric widths do not have a selvage edge and when it is desired that no raw edges be exposed. These seams would be used to close wing and tail surface coverings.

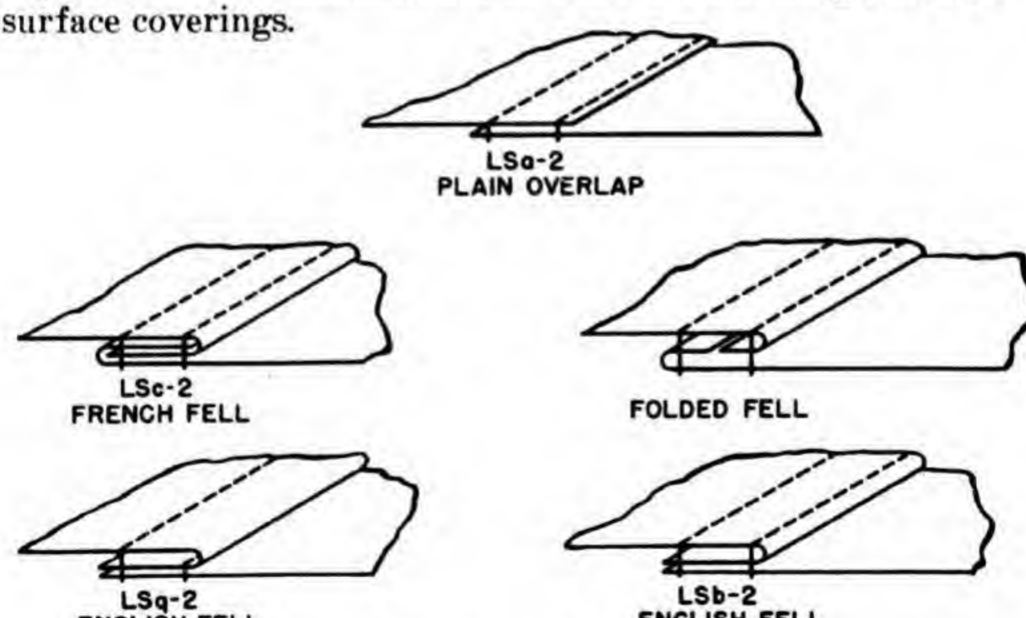


Figure 197.—Types of seams.

After a covering is applied it is necessary to close up the final openings. This is sometimes done by tacking on wooden wings, but sewing is preferable. In hand sewing, a baseball stitch, as shown in figure 198 of six to eight stitches per inch, is used. It is finished with a lock stitch and knot. Holding the fabric under tension preparatory to hand sewing can be done by pinning the fabric to a piece of adhesive tape pasted to the trailing edge of metal wings.

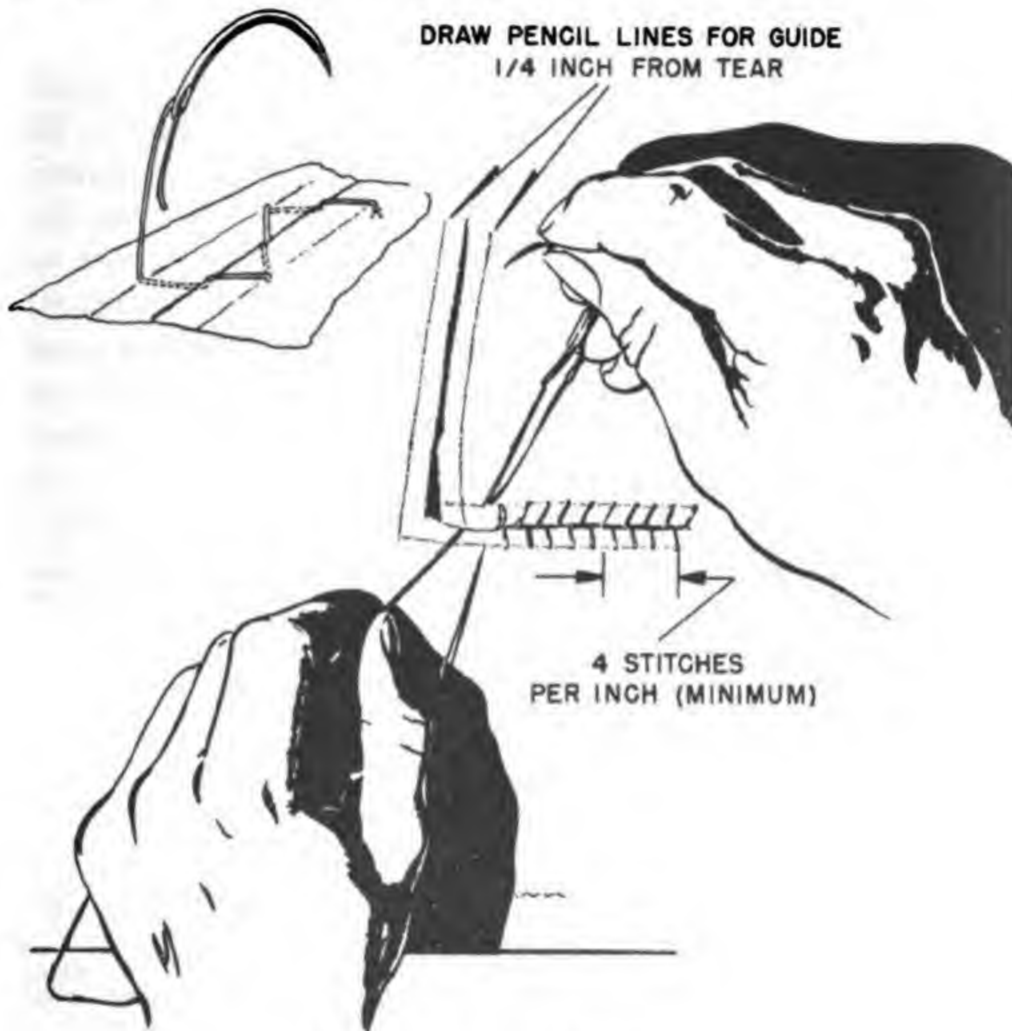


Figure 198.—Baseball stitch.

Thread for hand sewing and lacing cord should be waxed lightly before using. The wax should not exceed 20 percent of the weight of the finished cord. A beeswax free from paraffin should be used for waxing.

All openings in the fabric—such as those for protruding fittings, inspection holes, etc.—should be reinforced with fabric patches. These patches may be either another layer of fabric doped on, or a leather patch sewed to the fabric covering. Patches should fit the protruding part as closely as possible to prevent the entrance of dirt and moisture.

The edges of the patch should be pinked 8 to 10 pinks per inch, or frayed at least $\frac{3}{16}$ inch so that they will adhere tightly to the cover.

The patching of small holes and V-shaped tears in fabric covering may be accomplished in the manner illustrated in figure 198. The patch may have either pinked or frayed edges. When repairing such tears and holes, care must be taken to insure that the repairs possess the full strength of the surrounding material and match the adjacent areas in appearance. This may be accomplished by giving the patch the same number of coats of dope as the original surface.

A PATCH MUST NEVER OVERLAP ANOTHER PATCH.—If a large patch is not feasible, or if the patch area must exceed half the section area, the complete fabric section affected should be replaced.

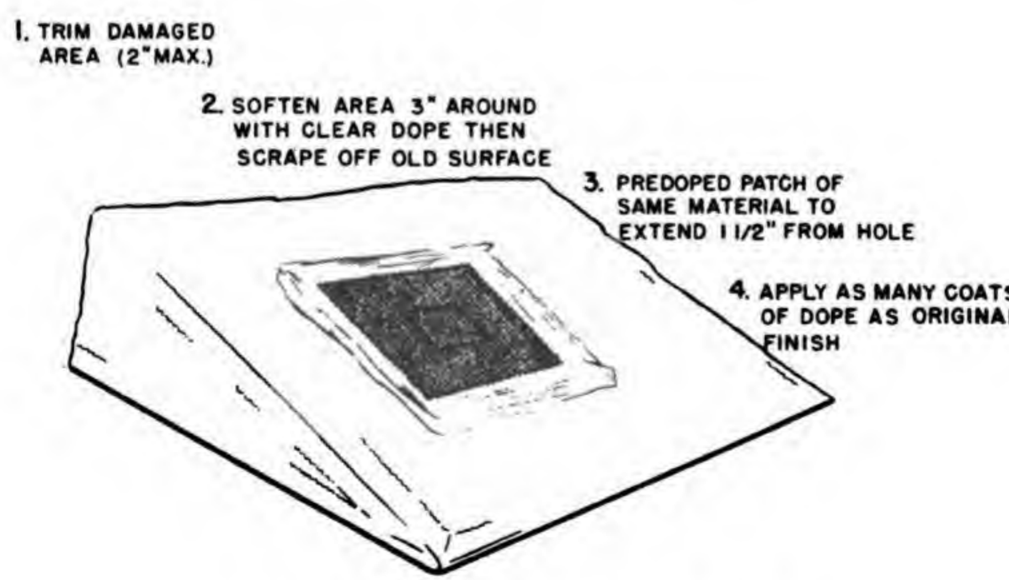


Figure 199.—Doped patch for fabric repair.

Where large tears and holes occur in fabric covering, they may be repaired by removing the damaged fabric and sewing in a patch. In cases of badly frayed tears, large tears, or large holes, cut out the damaged portion of the fabric to a triangular or rectangular shaped opening, as illustrated in figure 200.

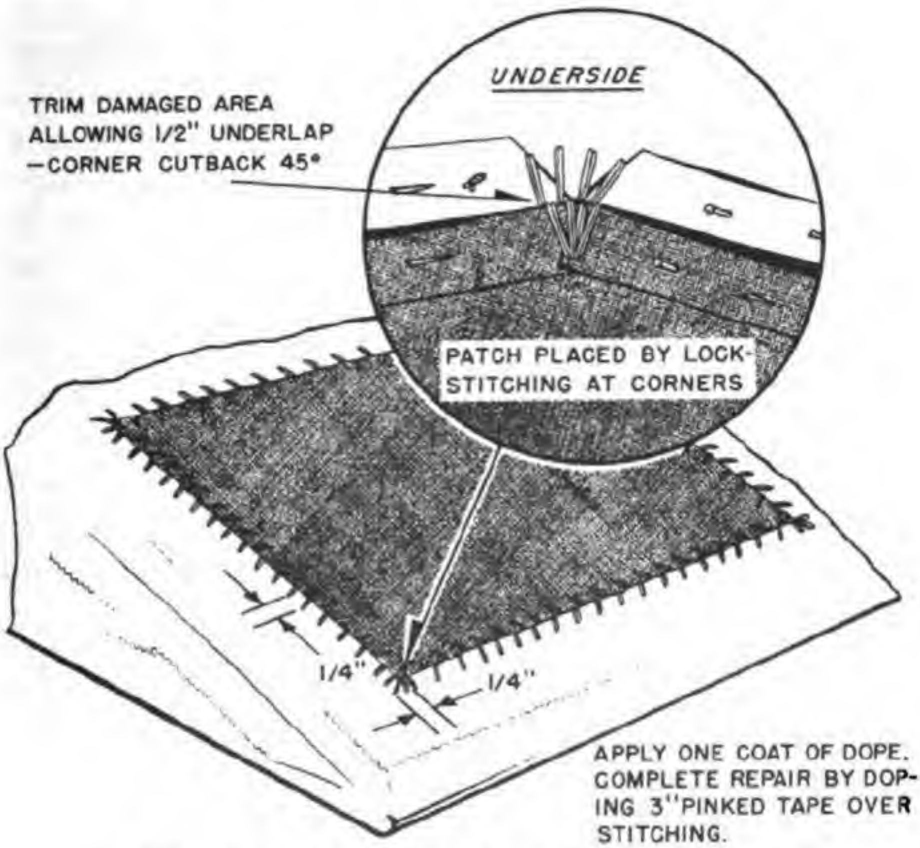


Figure 200.—Typical fabric patch repair (sewed patch).

After the fabric has been cut out as directed, fold all edges of the original fabric to extend at least ½ inch beyond the opening on all sides.

The next step is to sew the edges of the opening. Temporary stitches at each corner facilitate seam stitching. Use a single strand of No. 8, 4-ply cotton, hand-sewing thread, and space the stitches close together. Use the baseball stitch when sewing. The tautness of the patch fabric should be such that, after doping, the surface tension will equal that of the original surface.

Airfoils may be covered with fabric by the envelope, blanket, or combination method. The envelope method is preferable and should be used whenever possible. In all methods, the warp of the cloth should run parallel to the line of flight.

The envelope method of covering airfoils consists of sewing up several widths of fabric of definite dimensions, and then running a transverse seam to make an envelope or sleeve. This sleeve is then pulled over the airfoil through its one open end, and the open end is then hand-sewn or tacked. If the envelope is of the proper dimensions, it will fit the airfoil snugly. When possible, the transverse seam should be placed along the trailing edge. The advantage of this method lies in the fact that practically all sewing is by machine, and there is an enormous saving in labor in fitting the covering.

The blanket method consists of machine sewing a number of widths of fabric together, placing it over the wing, and hand sewing the transverse seam along the trailing edge.

The combination method consists of using the envelope method as much as possible, and the blanket method on the remainder of the covering. This method is applicable to wings with obstructions or recesses that prevent full application of an envelope.

After the cover is sewn in place, reinforcing tape is placed over each rib, and the fabric is laced to each rib. Except on very thick foils, the rib lacing passes completely around the rib. On thick wings, the lacing passes around one chord member only, but both top and bottom surfaces must be laced in this manner.

The lacing should be as near as possible to the capstrip. Each time the lacing cord goes around the rib, it is tied over the upper center or edge of the rib, and then the next stitch is made at the specified distance away. The first and last stitches are made with slip-knots to provide for tightening these stitches, while all other stitches are tied with a non-slip or seine knot. Rib lacing should extend from leading

edge to trailing edge, except when the leading edge of the wing is covered with plywood or metal. In these cases, the lacing should start immediately after these coverings.

Figure 201.—Covering an airfoil.

DOPES AND DOPING

In order to tighten fabric covering, and to render it air- and water-tight, the cloth is brushed or sprayed with dope. This dope also protects the fabric from deterioration by weather or sunlight, and when polished imparts a smooth surface to the fabric which reduces skin friction.

Dopes must be applied under ideal conditions to obtain satisfactory and consistent results. A clean, fresh, dry atmosphere with a temperature above 70° F., and a relative humidity below 60 percent, combined with good ventilation, is necessary in the dope room. The dope must be of the proper consistency and applied uniformly over the entire surface.

The number of coats of dope applied to a fabric surface depends upon the finish desired. It is customary to apply two to four coats of clear dope, followed by two coats of pigmented dope.

Panels should be doped in a horizontal position whenever possible to prevent dope running to the bottom of the panel. The first coat of dope should be brush-applied and worked uniformly into the fabric. A minimum of 30 minutes under good atmospheric conditions should be allowed for drying between coats. Surface tape and patches should be applied just prior to the second coat of dope, which should also be smoothly brushed on. A third and fourth coat of clear dope can be applied by either brushing or spraying. These coats of clear dope provide a taut and rigid surface to the fabric covering. If desired, this surface may be smoothed by lightly rubbing with 6/0 or 7/0 sandpaper or a similar abrasive.

QUIZ

1. What is one of the chief reasons for using fabric as a covering for control surfaces?
2. What should the thread count for aircraft fabric be?
3. Why does machine sewing thread have a left-hand twist?
4. What direction should the warp of the cloth run for covering flight surfaces?
5. What is the chief advantage of the envelope method of covering airfoils?
6. What temperature and humidity conditions are best for applying aircraft dope?

APPENDIX I

ANSWERS TO QUIZZES

CHAPTER I

AIRCRAFT STRUCTURAL MAINTENANCE

1. Fuselage, engine mounts, wings, stabilizing surfaces, and control surfaces.
2. Station webbs are located so as to carry concentrated loads.
3. Mounting the engine and its equipment so that it is accessible for maintenance and inspection.
4. Cantilever design.
5. Ailerons, elevators, and rudder(s).

CHAPTER 2

BASIC STRESSES AND METAL PROPERTIES

1. Fatigue failure.
2. Torque.
3. Brittleness.
4. Malleability.
5. Pounds per square inch.

CHAPTER 3

BLUEPRINT READING AND LAYOUT

1. Exposure to light and subsequent rinsing in water of chemically treated blueprint paper.

2. The lines on the original drawing or tracing made from the original protect the treated blueprint paper directly beneath them from exposure to light.
3. In its title block.
4. Approximately where on a drawing a particular part number will be found.
5. The location of a particular part of the structure from a reference point.
6. Thickness, width, and length.
7. The extreme permissible dimensions of parts.
8. The range of error between limits.
9. Three views.
10. Three.
11. Visible outlines, hidden lines, dimension lines, extension lines, center lines, alternate position lines, break lines, and cutting plane lines.
12. By using base line dimensioning.

CHAPTER 4

FABRICATION PROCEDURES

1. Simple lap, grooved, and standing.
2. Two and a half times the diameter of the wire.
3. The bend allowance.
4. The base measurements.
5. The bend tangent lines.
6. 2S.
7. By crimping the edge of the metal and then hammering out the crimp.
8. Length of joggle approximately three times the height.

CHAPTER 5

RIVETS AND RIVETING

1. On relatively thick sheets where strength is required.
2. Brazier head rivets.
3. 24S–T.
4. 0.002 to 0.004 inch.

5. Type A.
6. $\frac{7}{16}$ inch.
7. The bucktail should equal one half the diameter of the rivet.
8. Three times the rivet diameter.
9. $1\frac{1}{2}$ inch.
10. Squeeze riveter.
11. 17S–T.
12. Saving in weight and ease of application.

CHAPTER 6

SHEET METAL FASTENING DEVICES

1. In sizes $\frac{3}{32}$ to $\frac{3}{16}$ inch. Sizes are indicated by colors.
2. Type Z.
3. Channel gang nuts or strip plates.
4. Oval head.
5. Rivnuts.
6. Shakeproog fastener, flush slotted heads, Army-Navy strength classification 500 pounds, sheet thickness of 0.055 to 0.064 inch.

CHAPTER 7

GENERAL STRUCTURAL REPAIR

1. To restore the injured or damaged part to its original condition.
2. Stressed and nonstressed.
3. By plugging it with a rivet.
4. 16 rivets.
5. 12 inches.
6. Rod types.
7. So that it can be used as a template.
8. 24S–T.
9. 2 pound.

CHAPTER 8

TUBING MAINTENANCE AND REPAIR

1. Structural and nonstructural.
2. Any fuel line tubing that is directly connected to the engine.
3. By the inside diameter.

4. If they are not cut square the tube and nuts may not fit properly.
5. Because aluminum alloy is light and does not work harden as as rapidly as copper.
6. Quench it in water if you have a tank large enough to hold the whole section of tubing.
7. Red, yellow.
8. 32.
9. 3⅜ inches.
10. In a ladle in boiling water.
11. It extends into the fitting a shorter distance than does the two-part type and therefore is more easily removed.
12. 52S.

CHAPTER 9

RUBBERIZED EQUIPMENT MAINTENANCE

1. Moderate temperature, darkness, low humidity, cleanliness, avoidance of sparking electrical equipment, and still or dead air.
2. Vapor-proof extension lamp, universal ball-socket type mirror, and a rounded pointed wooden dowel.
3. Inside.
4. Absorb shock of projectiles.
5. Every 30 hours.
6. 4 years.
7. None.

CHAPTER 10

REPAIR OF TRANSPARENT PLASTICS

1. Acrylates (Methacrylate), acetate (Cellulose acetate).
2. Acetates.
3. Lip angle of 70° or point angle of 140°. Lip clearance angle should be 4° to 8°.
4. Drilling holes at the end of the crack.
5. Acetone.
6. Cut out damaged area and replace it with a plug of thicker material.

7. Monocurved (simple) and multicurved stretch forming.

CHAPTER 11

REPAIR AND APPLICATION OF FABRIC COVERING

1. Fabric is not subject to fatigue failure.
2. 80 to 84 threads per inch.
3. Because some sewing machines have a tendency to untwist right-hand twisted threads.
4. The warp of the cloth should run parallel to the line of flight.
5. Practically all sewing is by machine.
6. A temperature of about 70° and humidity below 60 percent.

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

AVIATION STRUCTURAL MECHANICS (AM)

RATING CODE NO. 810

General Service Rating

Aviation structural mechanics maintain and repair aircraft surfaces, structures, and hydraulic systems. Align structural parts, such as wings, elevators, ailerons, rudders, and fuselage structures. Prepare, paint, or dope aircraft surfaces. Repair rudder, plastic, fabric, and wooden structures used in aircraft construction.

Emergency Service Rating

Title	*Abbreviation*	*Rating code No.*	*Definition*
Aviation Structural Mechanics S.	AMS	811	Perform shop and line maintenance in repairing, alining, and installing aircraft structures.
Aviation Structural Mechanics H.	AMH	812	Perform shop and line maintenance of aircraft hydraulic systems.

Group code Nos.	*Group titles*	*General service*	*Emergency service*	
		AM	*AMS*	*AMH*
53300–53399	Airplane hydraulics mechanics	X	------	X
53500–53599	Airplane accessory repairmen, miscellaneous	X	X	X
53900–53999	Aircraft sub-assemblers and installers, A&R	X	X	------
54100–54199	Aircraft metal workers	X	X	------
54200–54299	Aviation welders	X	X	------
54300–54399	Aviation heat treaters	X	X	------
54400–54499	Aviation electroplaters and anodizers	X	X	------
54500–54599	Aviation molders	X	X	------
54600–54699	Aircraft control riggers	X	X	X
54900–54999	Aircraft metal workers, basic	X	X	X
59300–59399	Aircraft salvage technicians	X	X	X
59500–59599	Aircraft painters, dopers and fabric workers	X	X	------
59600–59699	Aircraft woodworkers	X	X	------
59700–59799	Aircraft plastic workers	X	X	------

Qualifications for advancement in rating	*Applicable rates*		
	AM 810	*AMS 811*	*AMH 812*
XXX.100 PRACTICAL FACTORS			
.101 TOOLS			
Use hand and power-driven tools commonly employed in shop and line maintenance of aircraft structures. Provide for adequate stowage and care of tools	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.102 MEASURING INSTRUMENTS			
Use various measuring instruments for purposes intended. Provide for adequate stowage and care of measuring instruments	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.103 BLUEPRINTS			
Read simple blueprints and drawings	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Read and work from blueprints and drawings	2, 1, C	2, 1, C	2, 1, C
Make working sketches for structural or hydraulic repair	1, C	1, C	1, C
.104 CONSTRUCTION			
Remove, repair, service, install, and aline as appropriate aircraft structures, control rigging, and fittings, including wings, control surfaces, tabs, landing gear, control cables, and fuselage structures	3, 2, 1, C	3, 2, 1, C	1, C
.105 CLEANING OF AIRCRAFT			
Clean aircraft surfaces, structures, and enclosures, using proper materials and procedures. Use steam for cleaning aircraft	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C

Qualifications for advancement in rating	*Applicable rates*		
	AM 810	*AMS 811*	*AMH 812*
.106 METAL WORKING			
Identify common aircraft metals, tubing, and fuel, oil, and hydraulic lines. Fabricate aircraft sheet metal parts, metal fittings, and tubing by cutting, flaring, bending, threading, and assembling. Use riveting tools and riveting machines. Use safety and bending wire where appropriate. Make repairs to metal structures, including stressed skin and frames	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Install and maintain hydraulic lines, including the replacement of packing and seals and the repair or installation of flexible hose	2, 1, C	--------	3, 2, 1, C
Braze, anneal, forge, and otherwise perform metal heat-treating operations encountered in aircraft structural maintenance	2, 1, C	2, 1, C	--------
Use sandblasting and plating apparatus for preparing metal surfaces, if activity to which assigned is so equipped	2, 1, C	2, 1, C	--------
.107 WELDING			
Set up oxyacetylene welding apparatus and perform simple welding and cutting operations on carbon steel	3, 2, 1, C	3, 2, 1, C	--------
Braze and silver-solder applicable metals. Weld ferrous and aluminum alloys	2, 1, C	2, 1, C	--------
Perform simple arc-welding operations on steel plates and tubes	1, C	1, C	--------
NOTE.—See xxx.400, instructions for testing and qualifing welders.			

Qualifications for advancement in rating	*Applicable rates*		
	AM 810	*AMS 811*	*AMH 812*
.108 HYDRAULIC SYSTEMS			
Trace through aircraft landing gear, bomb bay, automatic pilot. brake, and other hydraulic systems; repair and service individual parts and linkages as required. Make periodic checks and inspections to facilitate preventive maintenance. Vent, bleed, drain, flush, and refill hydraulic systems. Remove, service, repair, and install hydraulic units and accessories	2, 1, C		3, 2, 1, C
Set up, operate, and maintain test benches for hydraulic units, and accessories	1, C		2, 1, C
.109—WOODWORKING			
Make repairs to wooden aircraft structures. Manufacture wooden forms, blocks, jigs, and templates for the manufacture or repair of aircraft structural parts	2, 1, C	2, 1, C	
.110 RUBBER, PLASTICS, AND FABRICS			
Repair rubber and plastic aircraft fittings. Make repairs to self-sealing fuel cells. Perform vulcanizing operations to patch rubber material. Repair tires and tubes. Repair fabric-covered surfaces	3, 2, 1, C	3, 2, 1, C	
.111 PAINTING			
Prepare surfaces for painting. Mask, dope, and paint, using spray gun, or brush. Mix paints according to specifications, using pigments, dryers, thinners, etc., as required. Make minor repairs to paint spray guns and accessories. Provide for proper care of equipment	3, 2, 1, C	3, 2, 1, C	

Qualifications for advancement in rating	Applicable rates		
	AM 810	AMS 811	AMH 812
.112 SAFETY PRECAUTIONS			
Observe general and local safety precautions pertaining to shop and line maintenance of aircraft structures, including the precautions to be observed when painting, using power tools, welding, fueling, or otherwise servicing aircraft	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.113 SUPERVISION			
Supervise and train personnel engaged in aircraft structural or hydraulic repair	1, C	1, C	1, C
Organize and administer:			
Metal repair shop	C	C	--------
Hydraulics repair shop	C	--------	C
XXX.200 EXAMINATION SUBJECTS			
.201 TOOLS AND MEASURING INSTRUMENTS			
Types, nomenclature, and uses of hand and power-driven tools used in the structural maintenance of aircraft, including those employed in metal working, woodworking, rubber, fabrics, and plastics repairs, painting, and the rigging of cable. Types, nomenclature, and uses of various measuring instruments employed in structural maintenance of aircraft	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.202 CONSTRUCTION			
Types of aircraft construction. Maintenance procedures for removing, installing, rigging, and aligning fuselage, structures, wings, tail surfaces, landing gears, tabs, control cables, cowlings, inspection plates, and fairings. Basic principles of the theory of flight and of weight and balance	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C

Qualifications for advancement in rating	Applicable rates		
	AM 810	AMS 811	AMH 812
.203 METAL WORKING			
Types, characteristics, uses, and identification markings of aircraft metals and tubing. Methods of riveting, safety wiring, and bonding. Identification of tubing and of gasoline, oil, and hydraulic lines by AN standard markings	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Processes for fabricating and joining metals. Processes and purposes of heat treating, including surface treatment for aluminum and magnesium alloys and corrosion resistant steels	3, 2, 1, C	3, 2, 1, C	--------
.204 WELDING			
Types and characteristics of welding apparatus and of welds. Welding processes, including use of material, technique, and safety precautions	3, 2, 1, C	3, 2, 1, C	--------
NOTE.—See XXX.400, Instructions for testing and qualifying welders.			
.205 HYDRAULICS			
Systems of aircraft that are generally hydraulically controlled. Principles of hydraulics for transmission of power. General repair, service, and maintenance problems common to hydraulic systems, including removal, testing, installation, and inspection of various units of such systems as the landing gear, brake, flap, bomb bay, automatic pilot, and booster control. Principles of instruments used in aircraft hydraulic systems. Lubricants and liquids used	3, 2, 1, C	1, C	3, 2, 1, C

Qualifications for advancement in rating	Applicable rates		
	AM 810	AMS 811	AMH 812
.206 WOOD, RUBBER, PLASTICS, AND FABRICS			
General properties of wood, rubber, fabrics, and various plastics and their uses in aircraft construction. Processes of repair, inspection, and testing of aircraft structures and fittings made from these materials	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Properties and methods of preparing and applying glues and rubber. Vulcanizing processes	2, 1, C	2, 1, C	--------
.207 PAINTING AND CLEANING			
Types, characteristics, and properties of paints, dope, varnishes, lacquers, pigments, driers, enamels, and thinners; and effects on color and properties caused by mixing. Types of hand and air brushes used and the methods of preparing and applying paint to aircraft surfaces. Methods of cleaning and caring for painting equipment. Types, characteristics, and uses of cleaning materials for cleaning aircraft surfaces and enclosures. Materials and methods used to mask surfaces and stencil insignia or numbers on aircraft	3, 2, 1, C	3, 2, 1, C	--------
.208 MATHEMATICS			
Basic mathematical principles as they apply to aircraft structural maintenance, as follows:			
Elementary principles of equations, powers, roots, and proportions. Work an elementary problem in weight and balance	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Basic principles of triangles, squares, parallelograms, circles and functions of right angles for computing metal shapes and forms	1, C	1, C	1, C

Qualifications for advancement in rating	*Applicable rates*		
	AM 810	*AMS 811*	*AMH 812*
.209 SAFETY PRECAUTIONS			
Local and general safety precautions pertaining to shop and line maintenance of aircraft structures, including those to be observed when painting, doping, welding, using power-driven tools, fueling, and otherwise servicing or handling aircraft	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.210 SUPPLIES			
Basic principles of Navy supply system, including procurement, stowage, custody, issue, and inventory	2, 1, C	2, 1, C	2, 1, C
.211 RECORDS AND REPORTS			
Common forms in use and the procedures for their preparation. Records kept and reports made for administering an aircraft structural maintenance activity	2, 1, C	2, 1, C	2, 1, C
.212 PUBLICATIONS			
General content and use of technical bulletins, publications, and catalogs pertaining to aviation structural repair	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
.213 ORGANIZATION			
Organization of own unit	3, 2, 1, C	3, 2, 1, C	3, 2, 1, C
Organization of own squadron or air department and relationship of other ratings to the Engineering Department	1, C	1, C	1, C

XXX.300 NORMAL PATH OF ADVANCEMENT TO WARRANT GRADE

Aviation structural mechanics advance to Warrant CARPENTER 7711 (Aviation Structural Technician) and assist Engineering Officers in repair and maintenance of aircraft structures.

XXX.400 INSTRUCTIONS FOR TESTING AND QUALIFYING WELDERS

NOTE.—Qualified welders (metal-arc and gas) are divided into three classes: welders, third-class; welders, second-class; and welders, first-class.

.401 QUALIFICATIONS FOR WELDERS, THIRD-CLASS

Pass the following qualifications test in accordance with the requirements of the General Specifications for Inspection of Material—Appendix VII—Welding, part E:

SECTION E-1: Test No. 1 in vertical and overhead position, using approved electrodes.

SECTION E-2: Test No. 1 in flat position only on steel, bronze, and cast iron, using applicable welding rods.

SECTION E-5: Tests Nos. 1 and 2.

Pass an examination on these subjects:

Welding symbols, types of welds, nomenclature, and definitions as set forth in sections A-1 and A-2 of the General Specifications for Inspection of Material—Appendix VII—Welding, Part A.

Uses of copper, brass, aluminum, iron, steel, and various alloys aboard naval vessels.

Preheat and postheat treatment of metals encountered in welding.

Various types of metal-arc welding sets.

Current and voltage necessary for various sizes and types of electrodes used in metal-arc welding.

Proper flames and technique to be used in gas welding and cutting of various materials, together with proper tip sizes that should be used.

Safety precautions to be observed with regard to welding, cutting, and to handling of gases used.

.402 TESTS AND QUALIFICATIONS FOR WELDERS, SECOND-CLASS

Must have served at least 1 year as welders, third class.

Pass the following qualification tests in accordance with the requirements of the General Specifications for Inspection of Material—Appendix VII—Welding, part E:

SECTION E-1: Test No. 4 using carbon molybdenum pipe and electrodes; test No. 1 in flat position only, on nickel-copper, corrosion-resisting steel, and aluminum, using applicable electrodes.

SECTION E-2: Test No. 3 using steel tubing and welding rods; test No. 1 in flat position on aluminum, using applicable welding rod.

Qualify to take charge of welding activities aboard ship and layout work for men on a job.

.403 TESTS AND QUALIFICATIONS FOR WELDERS, FIRST-CLASS

Must have served at least 1 year as welders, second-class.

Take charge of a welding shop aboard a tender or repair ship, layout, and properly supervise the work.

Instruct and qualify candidates for welders, third-class and second-class.

.404 QUALIFICATION AND REQUALIFICATION

The period of qualification of welders shall be for 18 months. Qualification or requalification tests will be conducted aboard repair vessels or aboard any vessel having the necessary equipment.

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